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THE ROYAL AERONAUTICAL SOCIETY

(Founded 1866*)*

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VOLUME XLIII

SOME ASPECTS OF THE MECHANICAL PROPERTIES, USES AND MANIPULATION OF ALUMINIUM ALLOYS.

By F. R. C. SMITH, of the Northern Aluminium Co.

(*Lecture delivered before the Manchester Branch on 8th December,* 1938.)

INTRODUCTION.

It may be said that the title of this paper covers too wide a scope to be dealt with satisfactorily in the time available and that as a consequence the treatment of each section will be of a sketchy nature.

This is undoubtedly a justifiable criticism, particularly from the point of view of a specialist, but the aim has been to present what it is hoped will be helpful information of a practical nature to builders of aircraft rather than aero engines. There is no intention to enter deeply into the technical aspects of the applications of aluminium and its alloys to aircraft, but rather to review some of the many problems and enquiries which have been encountered during several years' contact with the aircraft industry.

As the title indicates, it is proposed to divide the paper into three parts. The first, dealing with mechanical properties, touches only upon those points which concern, firstly, the practical rather than the metallurgical side, and secondly, the classification of the alloys for comparison purposes when the uses are being considered.

The second deals with the applications of aluminium alloys in their various forms and a review of some of the recent developments in each case.

In the third will be submitted some suggestions for overcoming some of the problems which arise from time to time in an aircraft works with particular reference to the need for co-operation between the constructor and manufacturer in selecting suitable grades of material.

Throughout the paper the term constructor should be taken to be the aircraft builder, and manufacturer to be the supplier of materials.

The alloys which are heat-treatable will be called strong alloys and those which acquire improved mechanical properties by cold work, common alloys.

MECHANICAL PROPERTIES.

In order to obtain the maximum advantage from the use of aluminium alloys for structural purposes a thorough understanding of their mechanical and physical properties is necessary. There are a very great number of alloys available nowadays, particularly for aircraft use, with strengths ranging from $5\frac{1}{2}$ to over 30 tons per square inch and with greatly varying mechanical characteristics. It is one of the objects of this paper to present as clearly as possible an idea of these properties, together with the effect upon them of methods of fabrication and service conditions.

The sheet alloys may be broadly placed into three groups, low strength alloys possessing good ductility and forming ability, used for pressing, and fairings where high mechanical strength is not necessary; medium strength alloys whose use at the moment is not very extensive; and high strength alloys carrying the main stresses in the structure.

SPECIFICATION SHEET ALUMINIUM ALLOYS.

Group.	Spec.	MECHANICAL PROPERTIES. .1% P. S. tons/sq.in.	U. T. S. tons/sq.in.	Elong. % on 2".
1. Cowlings, Fairings, Tanks, etc.	BSS.2L17	-	5-6½	Bend Test.
	BSS.2L16	-	7-8½	Bend Test.
	BSS.2L4	-	9	Bend Test.
	DTD.213	-	11	Bend Test.
2. Cowlings, Panelling, - Skin coverings, Pressings, Spinnings.	DTD.346	-	11	20
	DTD.278	-	11	18
	DTD.182A	-	20-25	20
	DTD.209A	-	12	18
	DTD.292	-	12	20
	DTD.180	6	14	Bend Test.
	DTD.266	12	14	5
	DTD.175	12	16	Bend Test.
	DTD.296	14	16	5
	DTD.249	14	16	5
	DTD.170	15	20	Bend Test.
3. Stressed parts, - Skin coverings. Etc.	BSS.L38	13.5	24	15
	BSS.4L3	15	25	15
	DTD.275	16	26	15
	DTD.177A	17	25	15
	DTD.170	17.5	28	15
	DTD.342	19	25	8
	DTD.351	19	25	8
	DTD.266	21	27	10
	DTD.356	21	27	8

FIG. 1*a*.

Alloys falling into the first two classes are almost entirely of the strain-hardened kind, and those in the third group are practically without exception, heat-treated. Examples of Standard Specifications covering these groups are (1) 2L4, 2L16 and 2L17, representing commercially pure aluminium in hard, half-hard and annealed tempers, and DTD. 213 aluminium manganese alloy; (group 2) the aluminium magnesium alloys represented by specifications DTD. 249, DTD. 292 and DTD. 296, and (group 3) the heat-treated alloys such as those conforming to 4L3, 5L1, L. 40, DTD. 351, DTD. 364, etc.

Criteria to bear in mind before choosing a material for a particular purpose are: ability to withstand the stresses imposed in service, simplicity of handling and working up of components, and price.

Characteristics necessary for material in group (1) are, firstly, reasonable mechanical strength, and secondly, ability to spin or deep draw. The ultimate tensile strength of these alloys varies from about 5½ tons in the annealed condition to 12-13 tons in the semi-hard rolled condition with corresponding elongation values of about 35 and 6 per cent.

In assessing the spinning or pressing properties of these strain-hardened alloys, elongation and Erichsen values are useful for comparison purposes, but other factors such as ratio of proof stress to ultimate tensile stress should be taken into account.

In general, of course, sheets with low ultimate and proof stresses and high elongation values are most satisfactory for pressing and spinning work, but the factor of most importance is the speed at which the material strain hardens under deformation. It is a valuable property of both commercially pure aluminium and of the aluminium-manganese alloy DTD. 213 that they both have a low rate of strain-hardening and are therefore very suitable for intricate pressings. Even in the three-quarter hard rolled state DTD. 213 is being successfully used for drop-hammered cowlings in which a considerable degree of "draw" and thickening are necessary; yet it would be impossible to produce the same cowling in one operation from the heat-treated alloys, although they may show elongation values higher than 25 per cent.

The speed of strain-hardening is a function of the alloying constituents and although most elements confer the property, the effect of some is more pronounced than others, alloys with fairly high percentages of magnesium being particularly prone to harden quickly under deformation. A notable exception is manganese, which, in amounts up to 1.5 per cent., has very little effect.

Of all the mechanical properties two only may be regarded as more or less the same for all aluminium alloys, these being the elastic moduli E and G, which remain practically constant at 10×10^6 and 4×10^6 respectively. In certain of the alloys, notably the high strength ones, these values have been increased by approximately 5 per cent. over those of pure aluminium, but the difference is not enough to be of real value.

There are, particularly in aircraft structures, components and members in which the design is such that advantage cannot be taken of the full tensile properties, an example of which is the skin covering of the semi-monocoque fuselage where the plating is generally made to carry the shear loads and to assist the stringers in carrying the tensile and compressive loads. Here the main factor governing failure is the resistance of the sheet to buckling caused by elastic instability, which in its turn is dependent, gauge for gauge and material for material, upon the elastic modulus. It is safe to predict that there will be developments in the future towards the use, for this purpose, of strain-hardened alloys in the semi-hard rolled state of the type shown in group (2), with an ultimate stress of 16-20 tons/sq. in. and a proof stress of 14-16 tons/sq. in. The proof stresses of these alloys compare very favourably with those of the materials at present generally used and their resistance to corrosion is very little inferior. It might be as well to point out, however, that a limitation to their more general use exists in the fact that being in a semi-hard rolled state they cannot be formed to any great extent, which confines their use mainly to flat panels and panels with single or only slight double curvature.

With the exception of E and G, no other properties are common to all the alloys.

Alloys in group (3) are almost entirely heat-treated, but can be further subdivided into single heat-treated and double heat-treated types. Both possess properties essential for carrying the main stresses in aircraft structures, but each has distinctive characteristics not possessed by the other. In general, the single heat-treated types are characterised by medium to high ultimate strength, proof strength about 60 per cent. of the ultimate strength and elongation in excess of 15 per cent. In the case of the double heat-treated types the effect of the precipitation treatment is to increase both the ultimate and proof strength, but more particularly the latter, which in most instances becomes over 80 per cent. of the ultimate strength. At the same time there is usually a corresponding decrease in elongation. Another favourable point which normally accompanies the greater strength of the double heat-treated alloys is a higher shear strength, and there is less variation in the tensile strength figures of extruded sections in the longitudinal and transverse directions.

There is, however, one point which might be mentioned, and that is that alloys of the latter type are inclined generally to greater notch sensitivity as shown by the Izod impact test than are the single heat-treated types. The difference is not great, but it is well to bear this fact in mind in fabricating parts and to avoid such discontinuities as inspector's stamp marks, deep scratches, etc., where stress concentrations might occur, though these, of course, are precautions which should be taken with any material.

It should not be assumed from this, however, that notch sensitivity or impact strength is related to either proof strength or to the type of heat treatment, as there is at least one non-specification alloy in the double heat-treated category with a very high ratio of proof strength to ultimate strength, and an impact strength which is amongst the highest of any of the alloys.

As with most wrought materials, there is a rough relationship between ultimate tensile strength and fatigue strength, or more properly " endurance limit " for aluminium alloys, the ratio varying with the type of alloy.

It is possible with any alloy, even when manufacture is carried out under very strict laboratory control, to obtain considerable variation in strength above the allowable specification minimum. When it is realised that the ultimate tensile strength of extruded material to 5L1 specification may vary from 26 to 34 tons/sq. in. it will be seen that it may be very misleading to quote a certain fatigue strength without reference to the other mechanical properties of the specimen from which the fatigue properties were obtained. It is possible to obtain fatigue properties widely varying from the average and control tensile test figures should invariably be considered in conjunction with the fatigue results.

A noticeable feature of wrought aluminium alloys is the fact that the ratio endurance limit/tensile strength is very much higher for strain-hardened alloys than for those of the heat-treated types. The heat-treated alloys show remarkable uniformity of results, the tensile-fatigue ratio being very close to 0.34 on a 20 million cycle basis for the majority of alloys.

Laboratory fatigue tests are generally carried out under ideal conditions, with generous radii at stressed positions and with specially prepared surfaces, conditions, of course, which are seldom met in service. It must be emphasised therefore that under working conditions the full theoretical strength is seldom realised owing partly to the sensitivity of most materials to corrosive influences when subjected to fatigue conditions. This includes materials which normally exhibit good resistance to corrosion under static stresses, and it is also due to sharp changes of section which are inevitable in most designs and to the effects of surface scratches, inspectors' stamp marks and similar imperfections. Fatigue tests, therefore, should only be regarded as a basis of comparison between materials tested under the same conditions.

Uses.

Sheet.

As stated in the previous section, the alloys fall into three categories and in the case of sheet include the following:—In group 1, for such purposes as cowlings, tanks, etc., there are 2L4, 2L16, 2L17 and DTD. 213. In group 2, for parts requiring greater robustness than would be given by a group 1 alloy and in some cases for stressed coverings, etc., we have DTD. 170, DTD. 249 and DTD. 296. In group 3, for fully stressed structures, DTD. 351, DTD. 177a, 4L3, etc.

There has been a great increase in the use of pressing and drop hammering as a consequence of the larger numbers of machines being produced in series. This indicates the need for a deep drawing alloy in the group 1 category to replace 2L4, which has hitherto given satisfaction under manual forming.

A parallel development has taken place in the motor car industry in that steels with high ductility are now available for pressed parts, which in many cases are to a certain extent stressed. The light alloy sheet manufacturer is fully alive to the need for such a material and certain proprietary alloys, not available to specification, hold out promise of a solution of the problem. Their further development for this particular purpose is required, however, and the co-operation of the aircraft constructor and the pressing manufacturer is vitally necessary to ensure success.

There is already a tendency for the group 2 alloys to replace the weaker ones and at the same time to contribute to the carrying of stresses, thereby eliminating redundant material. That they have usurped the province of the stronger group 3 alloys to a certain extent is shown by the application of DTD. 296 as a structural and skin covering material for the C.W. Cygnet. In this machine the alloy in the ¾H temper giving a 0.1 per cent. proof stress of 14 tons per sq. in. is used for ribs, stringers, frames, and all surface coverings.

Such a departure from usual practice leads to the belief that in the use of such strain-hardened alloys lies the possibility of producing an all-metal aeroplane at an economical price.

Other applications for which they are coming into favour are for covering the surfaces of control members such as ailerons. In many cases where a double curvature exists and where such panels have been made from strong heat-treated alloys, the distortion from quenching has caused difficulty. This does not arise with an alloy such as DTD. 296 or DTD. 177a.

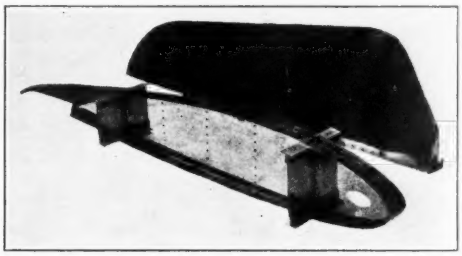


FIG. 1.

The natural corrosion resistance of most of these alloys is very good. In the design of the Cygnet anodising was considered unnecessary, the sheets being clear lacquered only.

The uses of alclad alloys are now almost universal and do not require elaboration. The question is sometimes asked as to the reason for the high corrosion resistance of these alloys. The protection afforded by the coating is a galvanic one due to the difference of electrical potential between the high purity coating and the alloy core when moisture is present to form an electrolyte.

Thus, sheared edges, scratches and rivets are protected, and while there is naturally some sacrifice of the high purity coating, this takes place at an extremely slow rate owing to its high resistance to attack.

It must not, however, be assumed that the alclad coating is immune from all forms of attack, irrespective of conditions of storage. At this time of the year especially, when changes of temperature and humidity of the atmosphere are very rapid, condensation can take place on stacks of sheet unless the temperature in the store is maintained at not less than 60°F.

When this takes place capillary attraction will cause moisture, laden with impurities, to penetrate between closely packed sheets and cause what is commonly known as " sweating " between the sheets. If some protection is not given prior to storing, " water staining " is liable to take place, which in severe cases may result in corrosion of the aluminium coating at points where moisture has been entrapped. In addition to temperature control, adequate ventilation round and under the sheets and coils should be provided by spacing. Sheets stored for lengthy periods should be periodically examined.

In the past there has been some reluctance on the part of designers to sacrifice the $1\frac{1}{2}$ tons/sq. in. proof stress in replacing 4L3 with L38, and while the introduction of DTD. 275 overcame this objection the production of DTD. 390 as an intermediate alclad alloy should assist in standardisation.

This latter sheet alloy is offered as a result of the demand for coated sheets with greater ductility than DTD 275 possesses and it is intended to replace not only L38 and DTD. 275, but also the uncoated alloys in view of their decline in popularity. While the 0.1 per cent. proof stress of DTD. 390 is 1 ton/sq. in. lower than for DTD. 275, it has been found that in almost every case replacement has been possible without serious alteration in design. Its ductility is equal

to that of L38, but greater power required for forming must be expected in view of its higher yield strength.

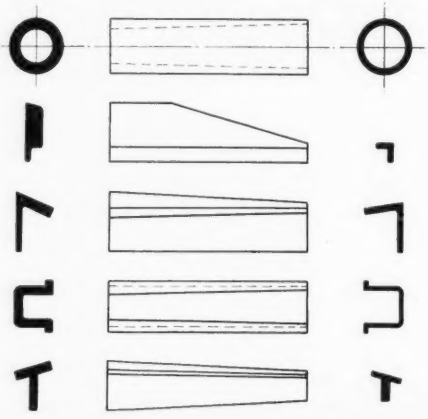
Not infrequently the alclad alloys are chosen on account of the good forming properties attributable to the softness of the coating, which is, of course, in the annealed condition. Apart from the lubricating effect of this surface, its junction with the core is not a sharp one, due to slight diffusion from the core into the coating during heat treatment. There is, therefore, a zone of transition having graded mechanical properties from high purity aluminium to alloy which reduces considerably the risk of cracking.

It has been frequently asked if the coarse grain which sometimes appears on the surface of a bend made in alclad is an indication of unsoundness in the underlying strong alloy. This is usually most noticeable when the part is heat-treated after bending, which subject will also be referred to later. It can be stated that such a phenomenon need cause no apprehension if the radius of bend is within the recommended limits and Fig. 2 shows that in such an instance the core metal is in a perfectly satisfactory state.

FIG. 2.

EXTRUSIONS.

The use of extruded sections in aircraft construction, at any rate as far as primary structures are concerned, has grown very rapidly, reflecting the speed with which aircraft designers have realised the value of their versatility.



TYPICAL FORMS OF TAPER EXTRUSIONS

FIG. 3.

Probably the most recent development lies in the availability of tapered extrusions. These may be produced either extruded with tapering area or by machining from parallel sections.

While the former method allows greater freedom in design in that rate of taper can be varied to suit change of stress, it is naturally more costly and the reduced rate of output may raise serious problems in time of emergency. The difficulty of straightening will also be appreciated. The alternative method is largely practised in aircraft work. It can consist of the production of a double section such as, for example, a channel which is subsequently sawn to form two angles with one tapering flange, or the area of the section, tee, angle, etc., may be diminished by milling or planing. Such examples are in regular production by manufacturers.

While there is practically no limit to the intricacy of form to which an extrusion can be produced, there are certain guiding principles to be taken into account in designing them if greatest ease of production is to be attained. Close dimensional tolerances may call for redrawing after extrusion and while such tolerances are required in the majority of cases, some latitude would materially assist output and ultimately reduce cost in those cases where fine limits are not so important. Possible increase in weight naturally plays a leading part in the matter, but is not necessarily involved. It is probably well realised that it is desirable to avoid rapid changes in section and also the use of a long tapered flange, for example.

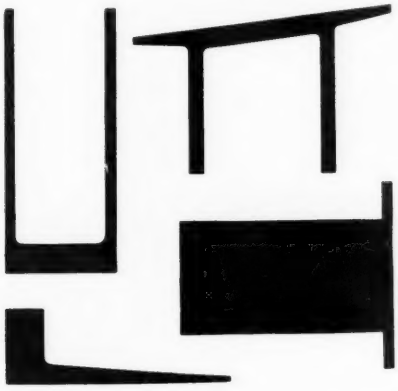


FIG. 4.

Such sections, apart from showing a tendency to " draw " from the die, if buckled in the thin sections as extruded will have their heavier portions stretched more in the straightening process with resultant drop in elongation.

While such buckling does not occur frequently, it cannot be avoided in certain cases in spite of careful die design.

The production of a deep channel involves redrawing to ensure accuracy and here the natural spring of aluminium alloys makes the elimination of longitudinal buckles and curved surfaces a costly process. In the example shown the redrawing required to produce accurately parallel legs may be quite considerable.

Different alloys extrude with varying facility and there are indications that where stiffness is the major consideration the softer alloys which can naturally be extruded more easily to thin sections merit some consideration. In particular certain proprietary alloys of the aluminium-magnesium-silicon type are eminently suitable for windscreen frames. They have generally good corrosion resistance, having been developed mainly for architectural work and in addition they possess good welding characteristics.

CASTINGS.

The advent during the last two or three years of alloy castings with high proof stress and guaranteed elongation values has greatly increased the popularity of this method of production of components previously considered mainly as forgings.

High strength castings have in the past been somewhat brittle and, therefore, subject to some suspicion, but as Fig. 5 shows it is now possible to obtain an alloy with a proof stress in the chill cast test bar of 17 tons/sq. in. and an elongation equal to that of the wrought alloys now commonly used.

ALUMINIUM SAND AND DIE CASTING ALLOYS.

Spec.	Form	MECHANICAL PROPERTIES. 0.1% P. S. Tons/sq.in.	U. T. S. Tons/sq.in.	Elong.% on 2".
DTD.361	S	20	21	1
	D	22.5	26	4
DTD.309	S	18	19	-
	D	19	22	-
DTD.255	S	17.5	18	-
	D	20	23.5	-
DTD.151A	S	15.5	16	-
	D	19	20	-
DTD.304	S	14	18	4
	D	17	24	9
DTD.245	S	13	15.5	-
	D	16	19	-
BSS.L.35	S	13	14	-
	D	14	18	2
DTD.250	S	11.5	14	-
	D	13	20	5
DTD.300	S	11	16	7
	D	13	18	12
DTD.276	S	11	15	-
	D	13	17	-
DTD.298	S	11	14	7
	D	15	18	10
DTD.294	S	11	14	3
	D	12	17	5

S = Sand Cast. D = Die Cast.

Properties quoted are for standard one inch diameter test bars.

FIG. 5.

Another deterrent to their use lay in the liability to porosity and while it cannot be said that this fault has been entirely eliminated it has been the subject of much intensive research. Moreover, the use for production purposes of modern X-ray equipment guards against unsound castings being passed and is a great aid to the founder in controlling his casting technique.

That castings in these alloys are coming into general use will be seen from the examples before you, but it may be of interest to enumerate some of the leading advantages which determine their adoption.

Primarily, of course, is the cost production, for sand castings in particular can be made at considerably lower metal prices than forgings, which they mainly replace.

Secondly, this production method ensures a closer approximation to the finished shape, thereby reducing or even eliminating machining.

Thirdly, parts can be cast which are quite impracticable as forgings without excessive machining or have hitherto been made by assembling from plate, rod and detail forgings or welded up in steel.

Finally, there is no definite orientation of grain so that strength is uniform in all directions.

The advantage of close approximation to finished shape mentioned above has been rendered more marked by the still more recent development of die castings in alloys to DTD. 361, 304, and 298, and although the cost of a die is usually only justified by reasonable quantities, it is frequently offset by the higher accuracy and uniformity in the finished article apart altogether from the value of the higher mechanical properties obtained.

It may be taken as a rough rule that elongation is a measure of resistance to shock loading and it will be seen that in the high proof stress range the alloys to

DTD specifications 361 and 304 are unique. Next of note is DTD. 300, which, while having relatively uninteresting tensile properties, possesses a combination of shear strength, elongation, low specific gravity and resistance to attack by salt atmospheres, that makes it a sound choice for shock loaded parts particularly on sea-going aircraft.

The uses of other alloys on the table are generally well known and are limited to those cases where stresses are not high or are steady and where stiffness is the main consideration.

Time does not permit of a detailed indication of the particular applications of the alloys in their various tempers, but examples will be found in the exhibits of such parts as control levers, brackets for equipment support, landing gear parts and so on.

The attainment of high mechanical properties with these alloys is unfortunately not accompanied by the same ease of casting as with the high silicon alloys, for example, and careful consideration of the foundry characteristics should be given in the design stage. Thus, the general requirements of castings that thick and thin sections should not be closely adjacent, that large thin areas should be avoided and so on are somewhat accentuated and radii in all cases should be generous. Where permissible, coring holes to make the metal thickness as uniform as possible should be introduced, this being particularly desirable with die castings.

Forgings.

The use of forgings and the considerations for good design are already too well known to need enlarging upon, but some brief remarks on the trend of development may be of interest.

Their high strength and uniformity of structure will always ensure their place in aircraft and attention has recently been mainly directed in developing more easily forged alloys and exercising greater control over grain flow. In the latter sphere may be mentioned the production of such parts as pistons, cylinders of

Fig. 6.

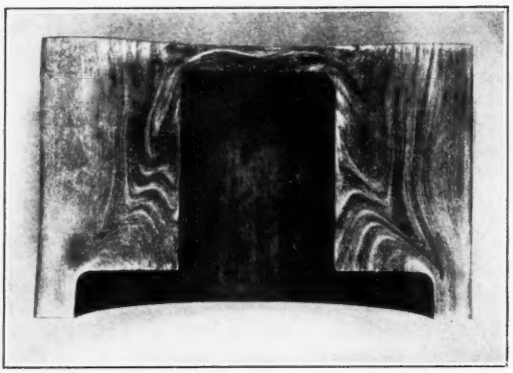


FIG. 7.

various types and propeller shank ends by the upsetting process, the grain flow being observable on Figs. 6 and 7 as the optimum for the working conditions imposed.

Close dimensional accuracy is now being obtained to a greater degree, particularly in propellor blades, the example shown requiring less than $\frac{1}{16}$in. machining over its entire surface.

It is somewhat difficult to give any useful indications of choice of alloy without going into details. 5L1 may be considered a sound general purpose alloy and has the advantage of superior corrosion resistance as compared with stronger alloys. By present day standards, however, it cannot be considered as easily forgeable, L. 40 and, to a more marked extent, DTD. 364 being more easily manipulated. While this factor is of more importance to the forge, the high mechanical properties of the latter alloys make them attractive to the designer especially as their transverse strengths closely approximate to the longitudinal values. Works managers also appreciate the fact that the artificial ageing which they receive often helps in releasing some of the quenching stresses which frequently become apparent only after machining in the case of the single heat-treated alloys.

MANIPULATION.

HEAT TREATMENT.

The fact that the strong alloys of aluminium require heat treatment for attainment of their maximum tensile properties is a combination of necessary evil and outstanding advantage. On the former account must be set against them the complication of equipment and processes needed for their use as compared with strain-hardened materials, while on the latter score may be considered that the facility to manipulate and to control mechanical properties is equalled only in the case of certain steels in which much higher temperatures are required.

That efforts are being made to ease the lot of constructors in this respect is shown by the recent introduction of DTD. 351 in the strong alloy sheet category and by the attention which is being paid to strain-hardening alloys, particularly those containing magnesium.

A most frequent cause of faulty behaviour of alloys under forming operations is incorrect or inaccurate heat treatment technique which leads one to believe that while the requisite mechanical properties are generally attained the material is not rendered as ductile as it can be by careful control. The fundamental requirement is that all parts of a load of metal shall reach the correct temperature as quickly and uniformly as possible and be held there for the time demanded by the thickness of gauge.

From this it is seen that the indiscriminate use of air furnaces in which the rate of temperature rise is slow is inadvisable for solution treatments of sheet. This applies particularly to components which have received a small amount of cold working owing to the risk of grain growth and also to the Alclad alloys in which it is desirable to reduce the time at elevated temperatures to a minimum in order to reduce the risk of excessive diffusion. Nitrate baths are, therefore, to be preferred.

For extruded sections, forgings, etc., electric or gas-fired furnaces with close control and forced air circulation are particularly suitable, as quenching equipment can conveniently be arranged adjacent to the loading doors. The time during which a load is in the bath is also of importance particularly where Alclad sheet is concerned and, depending on the weight of metal involved, will range from about eight minutes for 26 gauge sheet to about 35 minutes for $\frac{1}{4}$in. material. It is, therefore, undesirable to use a uniform time cycle of operations irrespective of the gauges being treated but rather to arrange that each load shall contain only material of approximately the same gauge when the time can be determined accordingly.

When sheets are being treated in a nitrate bath they should be spaced from one another preferably in a vertical attitude to permit free circulation of nitrate and the ratio of load to volume of nitrate be so regulated for the batch that the rise and fall in bath temperature shall lie within the prescribed limits. If sheets or strips are allowed to lie one upon another the mechanical properties may be obtained, but inferior ductility and possibly cracking result. This is due to the metal not having been at the correct temperature for a sufficient period to ensure complete solution of the constituents.

When small blanks are being treated the trouble of providing suitable racks with hooks will be amply repaid by reduced rejections or scrap. For sheets of moderate size it is preferable to use a cage with provision for spacing between adjacent sheets.

It is advisable to maintain a depth of not less than 2in. of nitrate below and 6in. above the load.

Quenching should be carried out as quickly as possible in clean cold water, which should not be allowed to rise above 50°C. (unless otherwise stated in the specification), by a continuous flow to ensure maximum corrosion resistance. The necessity for thorough washing in warm water to remove traces of nitrate is generally appreciated.

For artificial ageing an electric, gas or oil-fired furnace is quite suitable provided the temperature control is trustworthy and a high velocity air circulation is maintained. When a considerable load is being treated it is essential to ensure that all parts are at the temperature for the required period. This applies with special force to the short time ageing treatment for extrusions. Over-ageing both in regard to time and temperature should be avoided on account of the danger of lowering of both tensile strength and elongation.

The practice to be adopted for annealing depends largely upon the material being treated and the desired final degree of softness and is determined by the equipment available for convenient use. It is a function of both time and temperature, recrystallisation occurring very slowly at low temperature and with increasing rapidity as it rises, being almost instantaneous at the critical temperature. In practice annealing is almost invariably carried out between 340° and 425°C., the former being the figure for most of the strain-hardened types.

A point which is sometimes overlooked, and which might well be stressed here, is the fact that there are essential differences of procedure in annealing strain-hardened alloys which are not susceptible to hardening by heat treatment, and those of the heat-treated type. Almost without exception strain-hardened alloys are annealed at 340°C., the rate of cooling being unimportant as no hardening can occur.

The normal procedure is to hold the load in the furnace until such time as all parts of the load have reached the desired temperature, and maintain for an hour at this temperature, after which it is removed from the furnace to cool, slowly for preference. An exception to this is pure aluminium which does not require soaking and may be removed as soon as the correct temperature is reached.

The above treatment when carried out correctly ensures that strain-hardened alloys will be in a condition of maximum softness. This treatment has been recommended and is often used for annealing heat-treatable material, but it should be understood that owing to the nature of the material, full softening is not attained. Such alloys, whether they have been heat-treated or are in the strain-hardened condition following working, cannot be fully annealed by this method, though it does soften them to an extent which is satisfactory for all but severe work. Where heavy forming demands the maximum possible softness, however, a different procedure is necessary.

This treatment consists of raising the load to a temperature of 420°C., holding for at least an hour, after which it is slowly cooled in the furnace at a rate of about 15°C. per hour, until it has dropped to 270°C. when it may be removed. The object of the soaking at high temperature is to take the hardening constituents into solid solution, and the slow rate of cooling is to ensure that these constituents are not retained in unstable solid solution but are precipitated out in the form of coarse particles. The tensile strength of a duralumin type alloy after this treatment will be from 10-12 tons per sq. in. and the yield point well under half this value. Strong alloys which have not previously been heat-treated but are in a strain-hardened condition as a result of pressing, rolling and so on should receive this process, but it is only necessary to take them up to 350°C. before slow cooling.

The above treatments are rather lengthy and cumbersome operations, but fortunately they are not often necessary as the partial anneal afforded by the shorter process gives ductility sufficient for most purposes.

A fact which should be borne in mind when annealing is that most of the alloys and pure aluminium in particular are prone to grain growth when heated after small amounts of cold work have been done upon them. This tendency is most pronounced in the germinative range, which for most alloys lies between 200° and 300°C. and it is, therefore, advisable to rush the load up through this range as speedily as possible.

It may be said that the outline given above is too generalised to be helpful, but conditions vary so greatly that too much stress cannot be laid on the need for a careful survey of the prevailing conditions in each individual plant.

This also applies to periodic examination of nitrate baths in particular. In investigating complaints from constructors of cracking during re-heat treatment (of DTD. 275 in particular) cases have arisen in which a survey by means of a wandering thermo-couple has revealed quite startling facts. In one case a zone was found to be 28°C. above the recorded temperature, this being due to the collection of sediment on the bottom of the tank, and in another an area of low temperature existed above sheets lying flat on their supporting cage.

Manipulation.

The methods of manipulation of aluminium and its alloys are too well known to demand detailed discussion in each case even if time permitted, but it is proposed to consider the more important aspects which bear on the main problem.

After the fundamental considerations of correct choice of alloy and temper for any given application the next most important fact is probably the relatively high coefficient of friction between aluminium and steel. It plays its part in almost every operation and merits careful thought if uniform success is to be achieved.

In press work the finish of tools generally receives close attention, but its equal importance when bending, folding and drawing is sometimes overlooked. As mentioned before, the Alclad alloys assist production considerably by virtue of

their soft coating, but even so operations which fail by cracking, dragging or tensional rupture can often be carried out successfully by highly polishing the tools and using a suitable lubricant.

In the simple vee block operation illustrated, the need for good finish on the outer radii is usually appreciated, but not so for the radius on the punch.

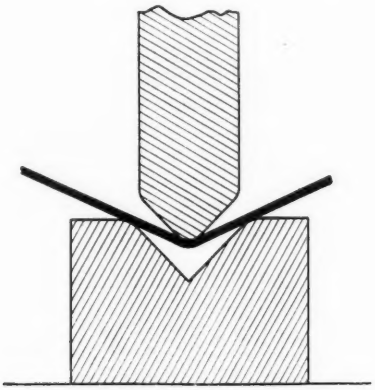


FIG. 8.

At this point it is desirable for the metal to thicken up if stretching only is to be avoided and consequently the surface of the sheet must be able to slide freely over the punch in spite of the concentration of pressure. This is fundamental in all bending operations and the finishing of tools by movement in the direction in which the metal will flow avoids the risk of scratches whose presence will retard its motion.

When drawing sections from strip the same precautions will frequently avoid localised pressure which causes warping and dragging.

The advent of the rubber press, which holds considerable promise in reducing the cost of detail production, seems to have given rise to another form of the same problem. Radii well within the scope of an alloy under pure bending cannot be achieved in the press and one is led to believe that the rubber in expanding round the form exerts a tangential drag which does not permit of any thickening on the inner side. Consequently the material used must be in its most ductile condition and unless an alloy is chosen which has low strain hardening properties it seems probable that radii as sharp as are achieved by other methods will be difficult to obtain.

This matter of coefficient of friction naturally brings in the subject of lubricants, the careful choice of which may mean success or otherwise in a difficult operation. In general, lubricants should have good body which consequently excludes to some extent the light grades of machine oil so frequently used. For drawing or deep pressing work an oil known among steam engineers as cylinder oil is very suitable as it will maintain a film of appreciable thickness even when drawing involves gauge reduction.

For folding, stretching and other kindred operations suitable proprietary brands of oil are available and a good quality of neutral soap dissolved to the consistency of cream has been found very successful and has the advantage that it is clean in use.

Reference was made at the beginning of this section to the matter of choice of alloy or temper. Fig. 9 illustrates one stage in such a determination for a part to be shaped on a hydraulic stretcher.

DTD. 213 in the quarter hard temper was found to fail by tearing and to determine the elongation required under working conditions one inch squares were ruled across the sheet and measured at breaking point. The results indicated that fully annealed sheet was required and to ensure retention of the maximum ductility the sheets were not stretcher flattened. It should be added that measurement of the squares all over the finished panel indicated that there was sufficient stretch at all points to harden the material to a satisfactory degree.

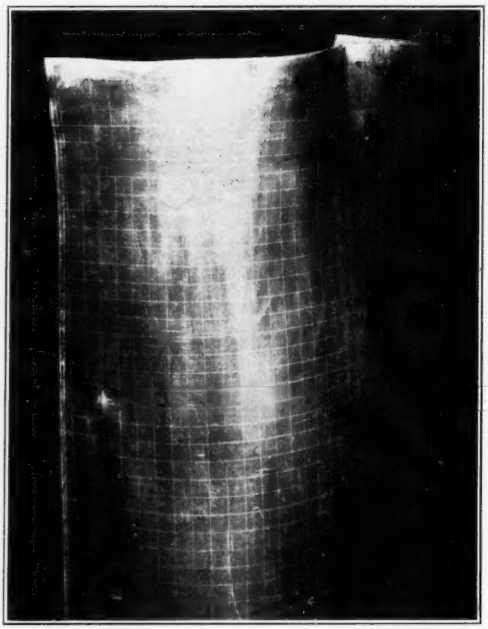


FIG. 9.

From this it will be also seen that where sheets are required for press work and the like it is a very definite advantage to specify to the manufacturer that a high degree of flatness is not required. A straightening operation to obtain flatness will, of necessity, reduce to a small extent the ductility.

A further point to be taken into consideration is the better bending properties of sheet when the bend axis is perpendicular to the direction of rolling. Too frequently blanks are cut without regard to this fact and where a part of circular shape is to be flanged as indicated in Fig. 10, sharper radii can be reliably produced at the north and south sides than at the east and west. In certain cases this may be a definite advantage from the design point of view.

The general heat treatment practice in forming the strong alloys when the deformation is too severe to permit the use of aged material is to solution heat treat and manipulate within an hour or so of quenching.

This method eliminates much of the distortion in quenching, but has many features with which users would gladly dispense. Manufacturers are very alive to the necessity of supplying to constructors materials which can be used in the condition as received and on this account the double heat-treated alloys have much to commend them. Thus L. 40, DTD. 351 or DTD. 364 solution treated would form the basis on which components are designed in those cases where use of the aged

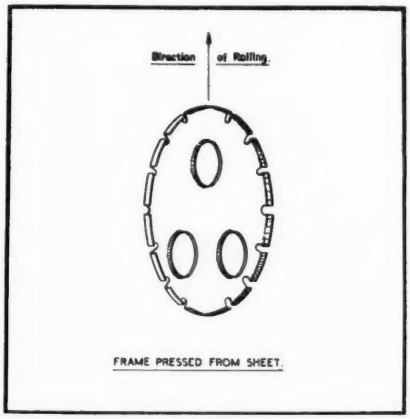
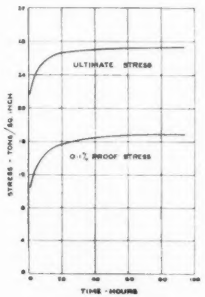


FIG. 10.



AGEING CURVE FOR 4L3 SHEET

FIG. 11.

material is not permissible. Artificial ageing is then required after forming, and already one machine has been planned for large scale production in this manner. The nitrate bath is replaced by a low temperature ageing furnace and while there is a justifiable criticism that the ageing is a longer process, it is possible to plan works progress with greater latitude. Moreover a very large bulk of parts or sub-assemblies can be handled by one furnace and night electricity tariffs exploited.

With such alloys, solution treated, slightly larger radii are required than those ruling for material in the quenched condition, but ductilities are comparable as far as Erichson and elongation figures are a criterion, although the higher yield strength of DTD. 351 than that of DTD. 275 in the quenched condition, for instance, means that greater power is necessary when forming.

Most of the double heat-treatable alloys age slightly after solution treatment, but in the normal way would have attained a stable state on reaching the constructor's works.

Experience in the use of certain of the double heat-treated alloys over a number of years indicates that forming in the quenched condition does not have a seriously detrimental effect on the properties after ageing. While this is borne

TESTS TO DETERMINE EFFECT OF STRETCHING IN SOLUTION TREATED CONDITION ON PROPERTIES IN FULLY AGED CONDITION - DTD.356 SHEET.

TESTS MADE AFTER SOLUTION TREATMENT ONLY.				
Sample No.	Time after solution treatment	MECHANICAL PROPERTIES. .1% P. S. tons/sq.in.	U. T. S. tons/sq.in.	Elong.% on 2".
1	30 mins.	-	18.8	22.0
5	45 "	-	18.4	19.0
9	60 "	7.55	19.25	21.0
12	7 days.	13.7	25.2	21.0

TESTS MADE AFTER STRETCHING AND AGEING.					
Sample No.	Stretch % of original elongation.	Time of stretching after solution treatment.	MECHANICAL PROPERTIES. .1% P.S. tons/sq.in.	U. T. S. tons/sq.in.	Elong.% on 2".
2	70	55 mins.	24.4	26.8	5.5
3	50	58 "	24.8	27.4	7.0
4	50	40 "	24.2	27.05	7.0
6	30	50 "	23.6	26.6	7.5
7	50	52 "	24.3	26.8	6.5
8	70	55 "	25.3	27.5	5.5
13	50	7 days.	25.2	27.6	6.0
TEST MADE ON AGED UNSTRETCHED SAMPLE.			22.2	27.1	9.5

FIG. 12.

out by the absence of failures in commercial service, some tests taken during a limited investigation may be of interest. They should not, however, be taken as indicating a generalised result.

When heat-treating spontaneously ageing alloys such as 5L1 prior to manipulation, particularly in the case of thick extruded sections, accurate temperature control and adequate soaking times are very essential. The resultant ductility decreases rapidly with fall in temperature and consequently the material should be heated as near the maximum permissible temperature as is safely possible.

In bending extruded sections the matter of lubricant is again of importance and the axiom perhaps more true than for sheet that aluminium responds best to gentle treatment. A bender of the three-roll or Kennedy type will frequently produce better results than a press.

One is sometimes asked how to prevent the collapse of flanges during a bending operation and where fixed restrainers are not feasible or desirable the use of notched hardwood blocks has been found of value on several occasions and may be worth mentioning.

Taking the case of the channel illustrated, the notched wooden strip is lubricated and inserted prior to bending and subsequently withdrawn.

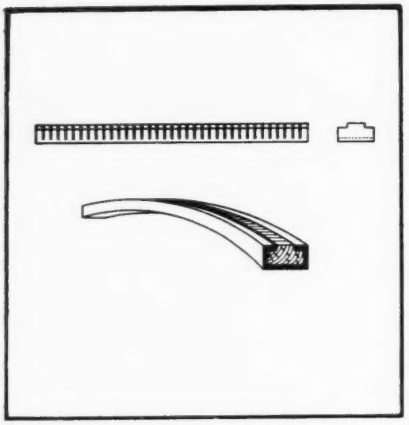


FIG. 13.

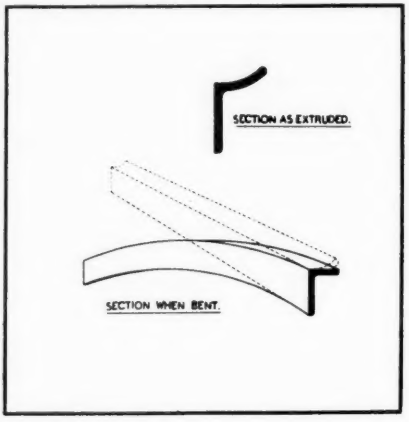


FIG. 14.

Its presence also helps to ensure some degree of uniformity of pressure not possible with a profile roll.

This is just one of many more or less well known workshop methods of preventing distortion of sections, but an alternative is sometimes feasible whereby this distortion is allowed for in the design of the section as originally extruded or drawn.

Thus, in the simple case of an angle which is to be bent to a known radius the section may be produced to a larger included angle so that when formed it shall collapse to its required 90°.

There is also the advantage that by this method the amounts of strain induced in the various parts will be to a certain extent equalised and consequently more severe bends made possible.

The factors governing rapid and successful machining of aluminium alloys are too well known to demand attention, with the exception possibly of one problem born of the increased use of extruded sections. It frequently happens that machining will release stresses imposed during manufacture, resulting in bending and warping. While the artificial ageing which double heat-treated alloys receive assists to some extent in removing quenching stresses, if the material

to be machined is ordered in the solution treated temper rectification of bends or twists is easier after machining and may offset the added cost of the subsequent ageing treatment.

The higher coefficient of expansion of aluminium than of ferrous metals also comes into play if adequate cooling of the work is not provided during machining resulting in inaccuracy of size. Moreover, if local overheating takes place buckling may then result, due to uneven release of quenching stresses.

Progress in Spot Welding.

The advantages of spot welded metal construction compared with riveting have been recognised for some considerable time. Costs can be reduced due to the elimination of processes necessitated by the riveting method. The cost of driving the rivet corresponds closely to that of the complete spot welding process, while the cost of drilling or punching and of inserting the rivets is obviated. Besides the question of cost, components will be lighter and the surface of the joint smooth.

In the early days of spot welding, aluminium and aluminium alloys were considered unsuitable for this type of joint. Their high thermal and electrical conductivities are detrimental to their easy welding, and, at first, machines of comparatively small capacity, as used with steel, were the only ones available. It was not until machines were produced capable of giving much larger values of current between the electrodes, and with accurate control of the whole process, including both electrical and mechanical pressures and timing, that it was possible to make satisfactory welds.

Recently success has been achieved by two distinct types of spot welding machines. In one of these types the electrical supply is alternating current and the thyratron or ignitron control equipment is utilised. The other type is a direct current operated machine consisting essentially of a magnetic circuit with a primary and secondary winding, but with a small air gap in the iron path. When the current in the primary reaches a predetermined value, it is interrupted by a contactor and a very heavy current is induced into the secondary winding which is connected to the electrodes.

Welds produced by either of these types of machines have now undergone very thorough tests with the result that for unstressed or lightly stressed parts such as cowlings, spot welding is now being employed on quite a number of aluminium alloys.

On the Continent and in the U.S.A. comparatively highly stressed parts are being spot welded, but here it is considered advisable that more experience should be gained on the less important components first, and this experience will then prove of inestimable value when the question of spot welding the more highly stressed members is considered.

Unfortunately, while the shear strength of spot welded joints is as good as, and often better than, that of riveted joints, spot welds are weak in tension, and care must be taken in the design of spot welded joints to ensure that the weld should not be subjected to tensile stresses.

One of the chief difficulties in the general application of spot welding has been the insufficient capacity of the machines for anything but very thin material, but A.C. machines of 500 k.v.a. and D.C. machines of 100 k.v.a. are now being produced, and it is anticipated that satisfactory welds in a material of a total thickness of $\frac{1}{4}$in., or even more, will be within their range.

Past research in this country has been restricted to a small range of alloys, principally to commercially pure aluminium, alloys of the duralumin type and alclad. There has also been some work on the aluminium magnesium alloy DTD. 296. These alloys appear to give satisfactory results, but it must be remembered that in the case of uncoated duralumin type alloys it is seldom possible to give good protection to the joint and that corrosion is likely to be rather severe.

The quality of welds depends largely on the surface condition of the sheets and it is essential that these should be absolutely clean and as free from oxide as possible. Thin wire brushes running at high speed may be used, but more consistent results can be obtained by chemical cleaning in pickling vats.

A convenient method of comparing the efficiency of spot welding is the ratio of the strength of one inch of width of joint to that of one inch of width of continuous metal. The following table gives the average of results obtained from tests on various alloys:—

Shear Strength and Efficiency of Spot Welds in Aluminium Alloys.

Specification.	Gauge.	Average shear strength per spot.	Efficiency per cent.	Number of spots.
BSS. 2L17 ...	0.064	210 lbs.	63	2
DTD. 296 ...	0.036	596 ,,	46	1
BSS. 4L3 ...	0.064	440 ,,	24	2
BSS. L38 ...	0.064	670 ,,	39	2

Gas Welding.

Blow-pipe welding cannot be recommended for the heat-treated alloys except in exceptional cases when it is possible to reheat-treat the article after welding and even then there are many difficulties, such as the hot short properties of most of these types of alloys.

Instances of the possibilities with the strain-hardened alloys are more common and with some of these, such as commercially pure aluminium, welding is recognised as being perfectly satisfactory.

It is, however, the stronger alloys in this class which are likely to interest the aircraft industry, and considerable research is therefore being directed towards the welding of the magnesium bearing alloys in particular. In one series of investigations the welding of DTD. 296 has shown that provided certain precautions are taken and that welding is not attempted on the very thin gauges (say less than 20 gauge), quite satisfactory welds can be made, and that an average tensile strength of over 12½ tons per square inch can be expected. This strength compares with an original tensile strength of 16 tons per square inch and of about 12 tons per square inch for annealed material. In this same series of tests the average shear strength was found to be more than 8 tons per square inch.

These results show that there are distinct possibilities for this type of joint and the reports of the research committees of the Institute of Welding should throw further light on this matter which is becoming of major importance.

NOTES ON AERO ENGINE RESEARCH.

By P. H. Rayner.

(Lecture read before the Students' Section.)

Introduction.

When the writer undertook the preparation of this paper, he rapidly discovered that it was not easy to find any branch of the subject which had not already been dealt with exhaustively by far abler pens than his. One or two matters have, however, been chosen about which information is somewhat meagre or scattered, and which may not, perhaps, be familiar to the aircraft engineer.

First a review will be made of the various types of electronic engine indicator which have been developed up to the present time; this instrument is coming into prominence now, and although it has by no means reached a state of perfection, it is a valuable asset in the hands of the research engineer for the study of fuel problems and other minor points.

The Electronic Engine Indicator.

The importance of obtaining an exact record of the pressure within engine cylinders for research purposes has always been recognised, but the high speed at which aero engines now operate has eliminated the mechanical, and even the most sensitive optical indicators. The Farnboro electrical indicator, even, is slightly subject to inertia, and gives a discontinuous record which at first led to a considerable amount of misconception as to the nature of detonation. The cathode ray tube, however, provides a virtually inertialess indicator, which is ideal for the purpose, though it owes its perfection more to television and electrical than to engine research. In essentials it produces a thin stream of electrons which are focused on a fluorescent screen at the end of the tube, where they produce a bright luminous spot; the composition of this screen may be varied according to whether it will be required for photographic or visual purposes. The electron stream is deflected vertically and horizontally by applying equal and opposite potentials to two pairs of plates arranged vertically and horizontally on either side of it near the source; the vertical plates are connected, usually through an amplifier, to a pressure unit which is attached to the cylinder, and produces potentials on the plates proportional to the cylinder pressure or rate of change of pressure. The horizontal plates are connected to a "time sweep unit" which supplies potentials corresponding to some function of the engine movements, so that the luminous spot traces a pressure-volume or pressure-time diagram on the screen, which may be photographed if a permanent record is desired.

The greatest difficulty has been to produce a satisfactory pressure unit, and it is proposed to give a brief review of the various types which have been tried. It should be remembered that the requirements of these units are very severe; they should be small enough to screw into a 14 mm. or even smaller hole; they must be insensitive to engine vibration, yet sensitive to the high frequency vibrations set up by detonation, and their characteristics must not be affected by high temperatures nor by the tightness of the unit in the head. It is also very desirable that the instrument should be capable of static calibration. The units fall broadly into six classes:—

1. Electro-magnetic: (*a*) moving coil, (*b*) moving diaphragm.
2. Resistance.
3. Capacitance.
4. Piezo-electric.
5. High frequency: (*a*) condenser, (*b*) inductance, (*c*) magneto striction, (*d*) inverse Wiedemann.
6. Photo-electric.

1. Electro-Magnetic.

(*a*) *Moving Coil.*—This type depends upon the voltage generated in a wire when it is made to cut lines of magnetic flux. The voltage is directly proportional to the rate at which flux lines are cut by the wire, so that the indications are proportional to the rate of change of pressure in the cylinders. It was the first type to be used and was later developed by the Massachusetts Institute of Technology (1); a section is shown in Fig. 1. An exciting winding *E* is carried

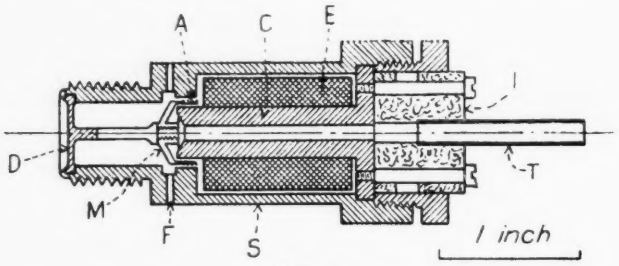


Fig. 1.

by a cold rolled steel core *C*, round the end of which is an annular air gap in which the moving coil oscillates. The diaphragm is heat treated alloy steel and the coil is carried on a light aluminium spider, fixed to a pillar projecting from the diaphragm which is air-cooled. The natural frequency of the diaphragm and coil is 10,000-11,000 so that the scope of this type of unit is very limited.

(*b*) *Moving Diaphragm.*—In this case the search coil is wound round a magnet movements of the diaphragm due to variation of cylinder gas pressure alter the air gap in the magnetic circuit and so generate potential changes in the windings of the search coils, the potential at any instant being proportional to the velocity of the diaphragm, so that " rate of change " diagrams are again produced.

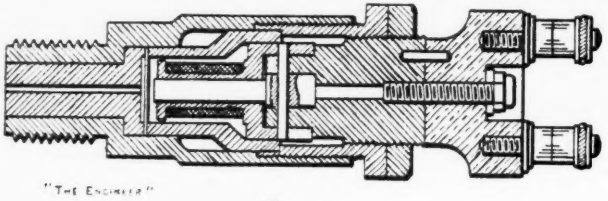


Fig. 2.

This type is still being developed both in this country and in America; a section of the Standard Sunbury Indicator (2, 3) is given in Fig. 2. It is necessary for the diaphragm to be made of a material having a high permeability, such as silicon iron, and unfortunately these materials have very poor heat resisting characteristics, so that it is necessary to incorporate a cooling passage for the gases. This is bound to introduce inaccuracy, and the original straight indicator

passage was found to give gross exaggeration to detonation ripples, due to resonance. In later models an attempt has been made to improve this by using a complicated passage system incorporating a damping chamber and five small holes leading to the diaphragm.

In Fig. 3 is shown a similar unit used by the Massachusetts Institute of Technology. It is water-cooled and the very thick diaphragm will be noted; this is doubtless due to temperature and vibration difficulties and must reduce the sensitivity. The natural frequency is nearly 100,000 cycles per second.

A rather different type is shown in Fig. 4. This has also been developed by the M.I.T. and is a moving shell inductor type. Flux is transferred across the generating coil by motion of a circular iron shell which is symmetrically located when no pressure acts on the diaphragm. The natural frequency of this type is not so high as that of the flat diaphragm type, and it is doubtful whether it would be suitable for detonation investigations.

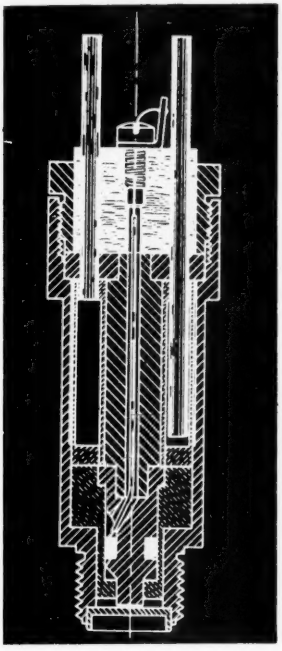


FIG. 3.

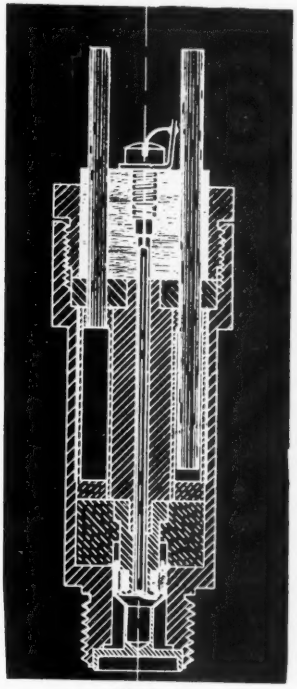


FIG. 4.

All the above mentioned units suffer from the disadvantage that they produce rate of change of pressure diagrams; these are difficult to interpret and enormously exaggerate vibration ripples in the pressure diagram, as well as detonation ripples. The diagram can be integrated electrically, but this involves further complication and uncertainty to an already involved electrical circuit.

2. RESISTANCE.

This is another type which was used in the early days, and has been developed both in this country by Dr. Dodds (4) of the Anglo-American Oil Co., Ltd., and in America by General Motors. In principle it depends on the variation in resistance which occurs when carbon powder or discs are compressed. A section

of one of Dr. Dodd's early designs is given in Fig. 5. The body and diaphragm are machined from the solid in stainless steel. A pile of ruby mica washers forms an insulating bush *M*, into which is inserted an adjustable metal plunger *O*. The clearance space between this and the diaphragm is filled with resistance powder, the most suitable being a mixture of filings from a radio resistance and powdered mica. The resistance of this varies with pressure, and can be arranged to give a deflection of the cathode ray proportional to pressure. The length of lead from this type of unit is strictly limited in order to reduce incidental capacities to a minimum. The temperature coefficient of this particular design was a serious obstacle and led to its abandonment.

Fig. 6 shows the next stage. The diaphragm is $\frac{3}{8}$in. diameter and 0.030in. thick, and the resistance element consists of a pile of highly compressed low resistance carbon discs. These are insulated by means of a glass tube and the unit is water-cooled; the upper and lower discs are copper-plated and sweated to the stainless steel cup and diaphragm. High resistance elements were also used, and even liquid resistance, but the vibration of the engine affected the results to such an extent that this type was abandoned also.

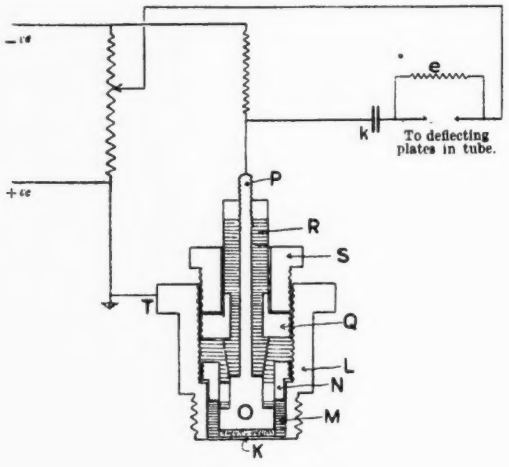


FIG. 5.

In America, General Motors developed a similar device (5) which was originally produced by the Bureau of Standards for recording strains in bridges, structures, ships, etc. A section is shown in Fig. 7 and it will be seen that two carbon piles are used, the pressure being applied to an arm which compresses one pile and releases the pressure on the other. The piles are connected up as arms of a wheatstone bridge, the out-of-balance caused by varying their resistance being used to operate an oscillograph of the cathode ray or galvanometer type. Here again it was found that much depended on the actual form of the carbon piles. The thin steel diaphragm is brazed in the end of the unit and is not intended to take any of the load, which is transmitted directly to the tongue; as this is comparatively cool the elastic properties do not change appreciably. The unit is air-cooled. The sensitivity varies greatly with the current flowing, which is affected by the temperature, but if the current is maintained constant the temperature effect is not great, as the variation of resistance due to temperature of one pile is offset by that of the other. The instrument can be calibrated statically, if necessary, at approximately the working temperature.

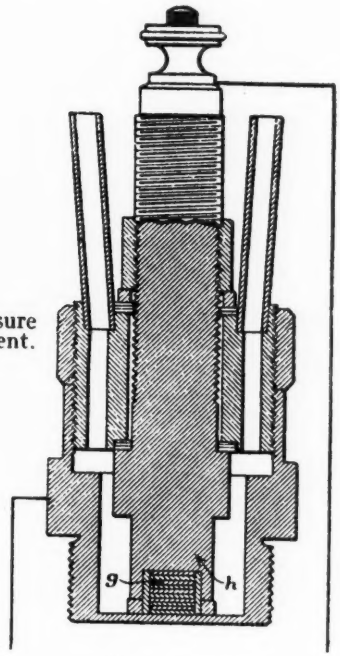


FIG. 6.

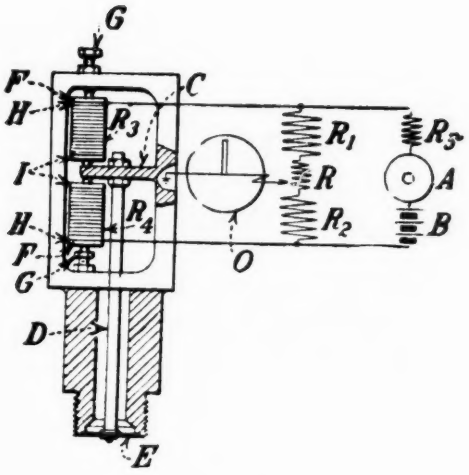


FIG 7.

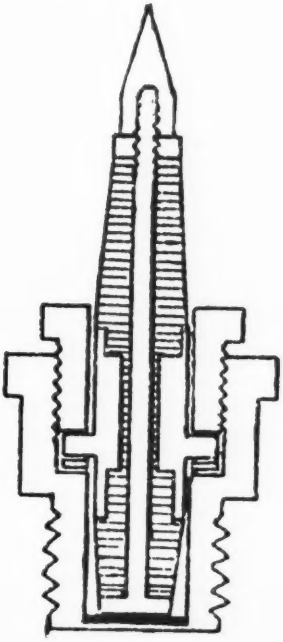


FIG. 8.

A rather different type is being manufactured in this country by Messrs. A. C. Cossor Ltd. The essential difference between this and the other resistance units is that in this case the resistance element is solid, and does not depend on machined contact surfaces for its characteristic. A rod of Erie resistance material is used; this consists of microscopic particles of silica coated with carbon, and the variation in the pressure between these particles varies the resistance. The elimination of a large amount of useless carbon greatly reduces the hysteresis effect, and the uncertain behaviour of carbon to carbon contacts is absent. The rod is inserted in a rubber tube and surrounded by water, so that the rod and diaphragm can be maintained at a constant temperature—an important point on account of the temperature coefficient of the material. The diaphragm is thin and does not absorb any of the load which is transmitted to the resistance rod. The design is very compact so that the unit can be screwed into a 14 mm. plug hole, and it is the most satisfactory resistance type so far produced.

3. The Variable Capacitance Unit.

This type makes use of the fact that the capacity of a condenser varies with the distance between the plates. The diaphragm is used as one plate and another charged and insulated plate is held a small distance above it, 1 or 2 thou. It will be seen at once that this type is prone to tightness, temperature and vibration effects and, therefore, cannot be calibrated statically. Dr. Dodds (4) has developed a unit along these lines and a typical section is shown in Fig. 8. The diaphragm is machined integral with the body, but it was found that an unsupported and uncooled diaphragm will not stand up to the high temperature and pressures which occur in aero-engines. Stiffening the diaphragm reduces the sensitivity of the unit and will not provide a satisfactory solution. The difficulty has been overcome by inserting a disc of mica between the condenser plates, that is, between the diaphragm and the central part of the unit. This serves the threefold purpose of supporting the diaphragm, helping to conduct the heat away from it, and increasing the capacity of the condenser roughly sevenfold. The condenser type lends itself readily to the production of either rate of change of pressure or ordinary pressure diagrams, by slight alteration of the amplifier circuit, and the main objections appear to be the difficulty of obtaining a constant calibration since an insulation resistance of 10^{11} ohms must be maintained, and the difficulty of eliminating external capacity effects. Dr. Dodds has published a considerable amount of information about his unit, and for further details reference should be made to one of his articles.

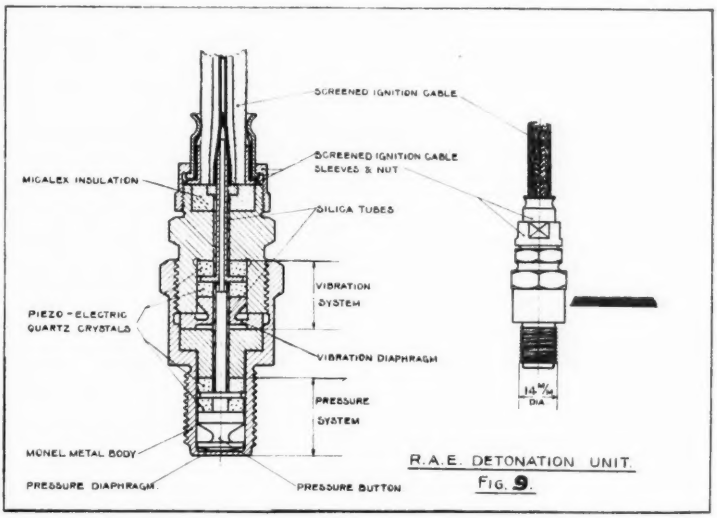
4. Piezo-Electric.

This type of unit makes use of the fact that when a quartz crystal is compressed it generates equal and opposite charges on the two faces under pressure. The charge is proportional to the applied pressure, and the piezo-electric constant is not affected by temperature up to 500°C., though if this figure is exceeded, the characteristics may be affected down to 300°C. At normal temperatures the charge only leaks away slowly, but as the temperature is raised the conductivity increases, so that the low frequency indications at operating temperatures are not reliable, and static calibration is not feasible. For the indication of detonation, however, this type of unit is very useful.

The unit used with the R.A.E. detonation meter is shown in Fig. 9. Two similar pairs of crystals are used, the lower pair is influenced by the cylinder pressure and the upper cancels out the effects of vibration, by producing equal and opposite E.M.F.'s. The charge is fed up the central electrode to an amplifier unit. As this unit is used with the detonation meter, in which low frequencies are deliberately filtered off, the leakage at the crystals is used as the first filter.

In Germany (6) a unit has been constructed with the piezo-electric crystals between two similar diaphragms: when the crystal is accelerated upwards by

vibration, the increased load on the top surface is neutralised by the decreased load on the lower surface, and vice versa, so that the unit should not be affected by vibration: sensitivity is reduced by half, since half the load is taken by the lower diaphragm, before it reaches the crystal. (Fig. 10.)



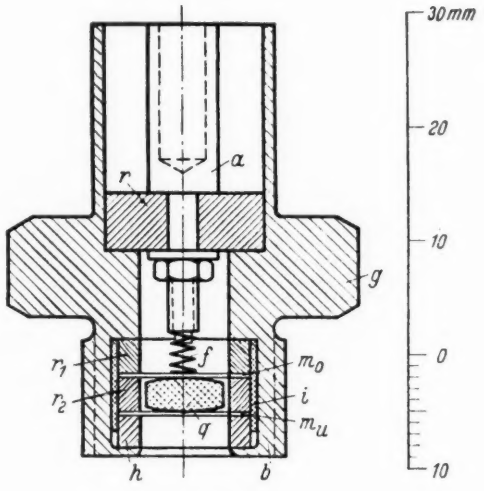


FIG. 10.

A piezo-electric unit has also been produced in America by the R.C.A. Mfg. Co., Inc. (7) and is shown in Fig. 11 but no provision is made for vibration, and temperature effects are ignored: This is also the case with the Zeiss Indicator Unit.

5. High Frequency.

Several units have been produced, in which a high frequency A.C. carrier wave is modulated in one way or another by the pressure variations in the cylinder. A " solid " band is produced on the screen by the carrier wave, the width depending on the pressure to which the unit is subjected: the method lends itself readily to static calibration and the time constant effect is eliminated, though it is not suitable for detonation indication, and is rather liable to be affected by external influences. The high frequency carrier wave can be applied to a condenser type unit, or a unit similar to the moving diaphragm electro-magnetic type in which a high frequency current is passed through a coil wound on a soft iron core; the current in this coil, or in a separate search coil wound on the same core, is modulated by the variation in impedance caused by the movement of the diaphragm; here again the difficulties associated with a high permeability diaphragm are encountered.

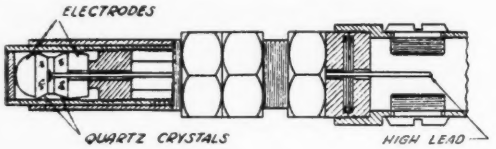


Fig. 11.

Another method makes use of the fact that when nickel is subjected to stress, it has a large magneto strictive effect. This property can be used to modulate a high frequency wave in a similar manner to the air gap high frequency type. The method has been developed by the Admiralty Engineering Laboratory and the unit is illustrated in a crude form in Fig. 12, which is extracted from a patent

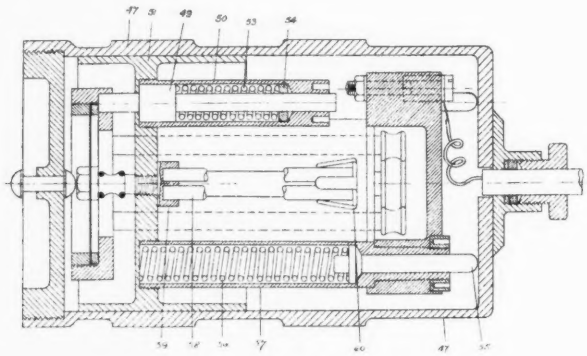


Fig. 12.

specification (8). In this case, four nickel rods are used, two in tension and two in compression, though in practice, of course, the design is considerably neater. As with all H.F. units a solid diagram is obtained, and high frequency pressure ripples within the cylinder are not distinguishable.

Another variation depends on the effect that if a ferro-magnetic wire or tube conducting an electric current is twisted it is longitudinally magnetised. This phenomenon, the inverse Wiedemann effect, has been utilised by the Japanese in an ingenious, if clumsy, unit, illustrated in Fig. 13. If a D.C. current is passed through the tube, the magnetic variation can be recorded by connecting a coil

wound over the tube to an oscillograph, provided the variations are of high frequency: if low frequency variations are to be measured the E.M.F. produced in the coil is very small and an A.C. current must be passed through the tube so that a modulated H.F. current is induced in the coil, the amplitude being proportional to the stress in the tube. The torque is applied through a piston and radius arm, and the unit illustrated appears to be quite unsuitable for high speed work, but a much neater arrangement might be devised, using a coil spring as the torque element. It will be noticed that the unit is arranged to operate as a sparking plug at the same time.

6. Photo-Electric.

The principle of this method is to screw a diaphragm, highly polished on the outside, into the cylinder head. A beam of light is focused on this and reflected back on to a photo-electric cell; as the diaphragm is deflected it varies the intensity of light reaching the photo cell and so a measure of the cylinder pressure is

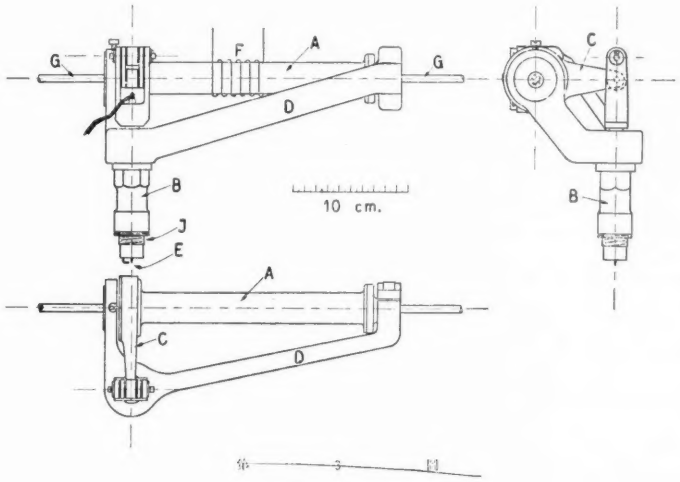


Fig. 13.

obtained. The method has been extensively used by Lebarthé, who has obtained some valuable results with it, though the diaphragm must be affected by temperature and the apparatus is rather bulky.

The Amplifier Unit.

It is not proposed to deal with this unit in detail, but to make a few general remarks about its possibilities and shortcomings. The greater the amplification which is necessary, the greater are the difficulties and distortion involved in the amplifier, so that a sensitive pressure unit which gives a large output is highly desirable. The electrical expert has a useful but dangerous weapon in his hands in the form of the amplifier: he can smooth out the imperfections of the pressure unit, such as vibration ripples, and so mask detonation effects, or produce plausible diagrams which bear no relation to what is going on inside the cylinder. Phase distortion which will produce a completely fallacious diagram, may also occur. For general purposes an even response over a wide range of frequencies is desirable, but for detonation research it is useful to cut out the lower frequencies, in varying degrees, for reasons which will be explained later.

THE TIME SWEEP UNIT.

These units fall into two categories—(*a*) those which give a pure time sweep, and are synchronised with some point in the engine cycle, either mechanically or electrically; (*b*) those which control the horizontal path of the spot on the screen to correspond with crank angle, piston displacement or some other engine movement.

The Dodds and Standard Sunbury indicators fall into the first class. The horizontal sweep is controlled by a variable condenser which is connected to the horizontal plates of the cathode ray tube; this condenser is charged at a uniform rate over the majority of a revolution, or any other convenient period, and is shorted by means of a contact breaker attached to the crankshaft during the remainder of the revolution. The rate of charging is controlled by a variable resistance and this alters the horizontal scale of the diagram. The exact time of any occurrence in the diagram can be measured by rotating the contact breaker until it occurs on some definite point on the screen: if the contact breaker is then rotated until some known point in the cycle occurs at the point, the crank angle between the two occurrences can be read off the graduated scale on the contact breaker. The diagram will not remain steady on the screen, however, unless the engine speed is absolutely constant.

In the second class come the Cossor and Zeiss indicators. In the Cossor type a photo-electric cell is enclosed within a cylinder outside which is a small lamp. The cylinder is cut away in such a way that, as it rotates, the intensity of light reaching the photo cell varies as the piston displacement, crank angle or any other convenient function of the engine movements. Lebarthé also uses a photo-electric time sweep unit. The Zeiss has a simple system in which a brush attached to the crankshaft rotates round a resistance, which is wound in such a way that the output gives a spot movement on the screen corresponding either to piston movement or crank angle.

The two latter types have the advantage that abscissa can be statically calibrated, and cyclical variations of speed are faithfully recorded by the spot; also no adjustment is necessary with engine speed variations, so that a steady diagram is obtained under all conditions.

DETONATION.

The cathode ray oscillograph engine indicator has proved of great value in the investigation of detonation phenomena, and there is now little doubt as to what happens inside the cylinder when detonation occurs. It is characterised by a very sharp pressure rise towards the end of combustion: this initiates pressure waves in the cylinder, which may continue down the expansion line, but the maximum cylinder pressure is not necessarily increased. The waves obey the laws of sound and their exact behaviour depends on the shape of the combustion space. In general, however, they travel transversely across the head at first, and this explains why the position of the pressure unit in the head is so important. If this happens to be placed at a node where there is no pressure variation, it will, of course, fail to give an adequate indication of the occurrence of detonation. The frequency of the waves depends principally on the cylinder diameter, and decreases as the piston descends on the firing stroke. If the combustion space is of very simple shape, and the pressure and temperature of the gases are known, it is possible to calculate the detonation frequency approximately, and the following figures give an idea of the values found in practice (1):—

Cyl. diam.	Frequency	
$3\frac{1}{4}$ in.	7,000—5,000	Decreasing in a linear manner with crank angle.
5 in.	4,500—3,500	

The behaviour of the gases after ignition is profoundly affected by the number and disposition of the sparking plugs, and this raises the point that when the

pressure unit replaces one of the plugs, detonation may occur, which would not occur with two plugs in operation.

When an amplifier is used between the pressure unit and the cathode ray indicator, it is possible to filter off the lower frequencies, and so indicate only the high frequency pressure oscillations occurring in the cylinder. It has been found that if frequencies below about 750 cycles per second are filtered off, under normal non-detonating conditions the familiar pressure diagram will have been eliminated, and a straight line will be seen on the screen. When detonation occurs, however, the high frequency pressure waves are clearly seen and it is the amplitude of these waves which gives a measure of the detonation intensity. This is the principle of the R.A.E. detonation meter; a piezo-electric pressure unit is connected to an amplifier whose peak frequency response is between 2,000 and 3,000 cycles per sec., the lower frequencies being filtered off. The output from the second valve is fed to the grid of a gas discharge triode: when the voltage on the grid exceeds its critical value, however momentarily, current passes through the valve and causes a luminous glow which continues until the circuit is broken and reset. The intensity of detonation is measured by applying a negative bias to the grid until the peak signal just triggers the valve—the amount of bias required gives the detonation intensity on an arbitrary scale. The triode circuit is automatically broken and reset at regular convenient intervals.

The frequency response of the amplifier has an important bearing on the knock rating of fuels, particularly if low frequency vibrations are included (9), and it is reasonable to assume that a truer comparison is obtained if only the frequencies above about 2,000 cycles per second are considered. The Midgley bouncing pin, which has been used as a knockmeter for many years, gives a rating corresponding to a maximum frequency response of about 400 cycles per second, and this may account to a certain extent for the discrepancy between standard knock ratings and those obtained on aero-engines.

There are so any variables which influence the knocking characteristics of a fuel, such as cylinder and intake temperatures, engine speed, boost pressure, and combustion space shape, that it is really impossible to define its properties by a single number, the octane number. A complicated series of curves showing temperature susceptibility, pressure susceptibility and so on, would be necessary, and one curve might possibly prove very valuable—that is, knock rating against frequency. The engine manufacturer could find the frequency response of his particular cylinder shapes, and would then be able to read off the fuel characteristics in those cylinders, instead of having to make extended fuel tests on each type of engine.

The most important influence on detonation, so far as the engine operator is concerned, is mixture strength; maximum intensity usually occurs in the portion of the fuel loop between the points of maximum power and maximum economy. For this and other reasons, rigid and accurate control of the fuel air ratio is of the utmost importance.

In practice the usual method is to use a normal carburettor with a mixture control operated by the pilot: this is highly undesirable because the pilot cannot be expected to regulate the mixture accurately, especially under service conditions. The problem has been tackled from two points of view, the obvious one of providing a fully automatic carburettor, and the illogical one of retaining the mixture control and attempting to provide a means of indicating the actual fuel-air ratio at which the engine is operating.

Fuel-Air Ratio Indicators.

The second solution of the mixture control problem, which is really a compromise precipitated by the advent of the constant speed airscrew, is the fuel-air ratio indicator: the pilot controls the orthodox carburettor, which is little more than a glorified tap, by means of a mixture control until the indicator shows that

the mixture is correct. There are several types of indicator on the market, but the most common is the electrical exhaust gas analyser. Actually the thermal conductivity of the exhaust gas is measured; the thermal conductivity depends principally on the amount of hydrogen in the gas, because although the percentage is never very high, its thermal conductivity is about six times that of the other constituents.

The percentage of hydrogen, and with it the thermal conductivity of the exhaust gas, decreases as the mixture is weakened, until, at the theoretically correct mixture, there is no hydrogen present, and the percentage of CO_2, whose thermal conductivity is less than the mean, is a maximum (10). If the mixture is further weakened the percentage of CO_2 decreases again, and oxygen (thermal conductivity above the mean) appears in the exhaust in increasing quantities (Fig. 14). Both these effects tend to increase the thermal conductivity once more, so that the instrument will reverse at the chemically correct mixture, and indicate a richening mixture when it is actually being weakened.

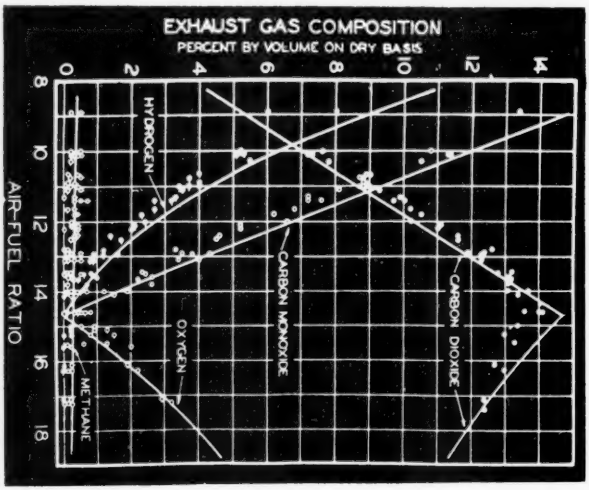


FIG. 14.

The general arrangement of the Cambridge mixture indicator is shown in Fig. 15. A sample of exhaust gas is led to the analyser unit, where it is filtered to remove as much moisture as possible, and then percolates into the analyser cells in which there are heated platinum wires. Two cells are filled with saturated air and two with exhaust gas; the resistance of the wires varies with their temperature which is governed by the thermal conductivity of the gas surrounding them. The electrical circuit is shown in Fig. 16; as the mixture is altered the balance of the wheatstone bridge is upset and the fuel air ratio is indicated on a suitably calibrated galvanometer. Apart from the objection that the instrument reverses at weak mixtures, there are other difficulties: the rate of flow of exhaust gas through the cell must be limited, and there is danger of water condensing in the analyser cells. Even when all is well from these aspects, there is a daily variation which is very hard to explain; at a given consumption the indicator reading may differ considerably from day to day, especially with rich mixtures. It may have nothing to do with the instrument itself—possibly the engine is burning the fuel in a rather different way. The author has tried eliminating every possible variable, but has been unable to track down the exact cause of the variation.

On the whole the instrument is little, if any, more reliable than the old 3 per cent. drop method, and in any case can only be regarded as a stop gap until the fully automatic carburettor is perfected.

EXHAUST TURBO COMPRESSORS.

Before concluding, a word or two about exhaust turbine driven blowers. Stratosphere flying will soon be here, as a regular occurrence, and it is at high altitudes that the turbo compressor comes into its own. The energy in the exhaust gas is more than sufficient to maintain the induction pressure at the same value as the back pressure, and as the power required to maintain a reasonable intake pressure

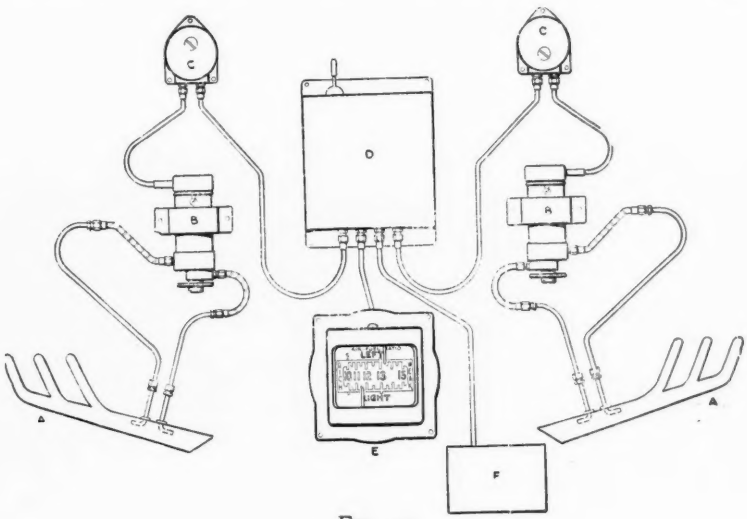


FIG. 15.

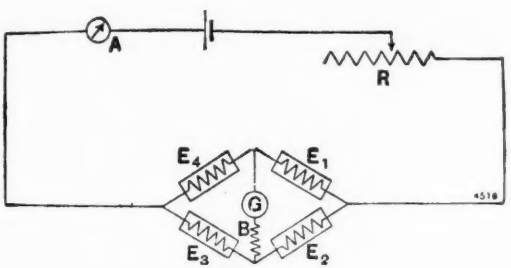


FIG. 16.

is quite considerable at high altitude, the exhaust turbo becomes well worth while. In the normal arrangement the whole of the exhaust gas passes through the turbine and the back pressure is kept as low as the requirements will permit. At 40,000ft. the atmospheric back pressure is only 2.7 lb./sq. in., but if this is increased to 14.7 lb./sq. in. in order to drive the exhaust turbine, a considerable loss of potential power will result.

If, however, the turbine is operated at a higher pressure, say 35 lb./sq. in., only about half of the exhaust gas required at 15 lb/sq. in. will now be necessary. With sleeve valve engines it is a simple matter to arrange auxiliary exhaust ports,

through which the first rush of high pressure gas can be fed to the turbines. When the cylinder pressure has fallen to 35 lb./sq. in., the auxiliary valves shut and the normal ones open to release the remainder of the exhaust gases against a back pressure of only 2.7 lb./sq. in. In this way the back pressure losses of the engine can be very considerably reduced. The main objection is that the operating temperature, already high, will be increased, but with modern materials and methods this should not prove insuperable. The idea is not new—it was patented in 1931—but in the opinion of the writer it is well worth at least a trial, for high altitude aero-engine work.

Conclusion.

An attempt has been made to indicate a few of the lines along which research is being done on aero-engines. Research takes time, and there is a great deal to be done, but it does not appear to be generally recognised that research is an urgent matter. A few thousand pounds spent on research may, in the end, save tens of thousands of pounds and vastly increase efficiency. It is, therefore, necessary to foresee the future trend of progress, so that when the time is ripe, the foundation for production has already been laid by research.

Acknowledgments are due to Dr. Postlethwaite, who has kindly given valuable help and advice in the preparation of this paper, and to the Air Ministry for granting permission to read it, while not necessarily agreeing with the views expressed herein.

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ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the
Directorates of Scientific Research and Technical Development, Air Ministry.
(Prepared by R.T.P.)

No. 62. DECEMBER, 1938.

Defence Against Parachute Troops. (Schenk v. Stauffenberg, Luftwissen, Vol. 5, No. 5, May, 1938, p. 174.) (62/1 Germany.)

Parachute troops may be divided into two classes: The first class comprises agents for intelligence, sabotage and propaganda. These troops are dropped in restricted numbers and may undertake small scale destructive work. The other class of parachute troops is intended to engage in active fighting and carry out large scale destruction in the interior of the country.

The defence against parachute troops can be considered under three heads:—

(1) Proper air control to prevent the break through of carriers.
(2) Provision of efficient and highly mobile columns to deal with landings.
(3) Organisation to repair any damage done as quickly as possible.

It goes without saying that the advent of parachute troops renders necessary the provision of some method of defence for all ground objectives. These defensive measures must prevent the enemy carrying out extensive damage and hold up the attack till the arrival of the mobile column.

To keep out spies and foreign agents will necessitate strict supervision of all lines of communication. It is important that the civil population be trained to co-operate in this work.

Italian Opinions on the Armament of the Fighter. (A. Serra, Luftwehr, Vol. 5, No. 7, pp. 271-3.) (62/2 Italy.)

The author compares the effectiveness in aerial combat of the 12.7 mm. and 20 mm. automatic guns, both guns firing explosive bullets with a muzzle velocity of 800 m/sec.

Taking a total weight of 120 kg. as available for armament, either two of the lighter guns (with 720 rounds) or one heavy gun (with 160 rounds) can be fitted.

Even if we take the same firing rate of 720 rounds a minute for each type, the two lighter weapons will be able to fire 10 bursts of 3 seconds each against only 4 bursts of the single 20 mm. gun. Although the weight of projectiles per burst favours the heavier gun (8.6 kg. against 5.8 kg.) the author is of the opinion that the increased number of bursts more than makes up for this. As a matter of fact, for reliability, the firing rate of the heavier gun will probably have to be less than the 720 rounds per minute assumed, in which case the projectile weight per burst may even favour the lighter guns.

Air fighting in Spain has clearly demonstrated that only close range engagements (of the order of 200 m.) are effective, and the extra number of bullets available with the 12.7 mm. calibre are decisive. As a matter of fact, for most work the 7.5 calibre gun with its high rate of fire suffices.

Engineering Aspects of Air Raid Protection. (H. Chatley and H. Gutteridge, The Engineer, No. 4322, 11/11/38, pp. 529-531.) (62/3 Great Britain.)

After some remarks on the terminal velocity of bombs and their destructive effort, the authors deal with attempts to increase the resistance of structure to attacks of this kind. No normal building can be designed to withstand a direct hit, the effects of the explosion can, however, be more or less localised in frame structures which are free from all brick or tile wall panels, the subdivision being carried out by means of expanded metal directly connected to the frame. The whole structure must be subdivided into units which are separately stable, ample window space being provided to allow bursting without injury to the frame. The improvement of old structure in fire resistance and strength is very difficult and expensive.

Probably few owners will be willing to spend more than 10 per cent. extra in structural provisions and more than 2 per cent. of gross costs in actual running precautions. Yet the minimum figures for A.R.P. are reckoned by the authors as 25 per cent. and 5 per cent. respectively.

As a result there is a tendency to accept the hazard as being cheaper than the remedy. As long as A.R.P. is voluntary, the costs become a penalty against the owner who spends them and are in favour of the one who does not.

Protection from Incendiary Bomb Fires. (Chem. and Ind., Vol. 57, No. 48, 26/11/38, p. 1125.) (62/4 Great Britain.)

A mineral paint for controlling fire from incendiary bombs has been evolved by Imperial Chemical Industries.

The new product, known as a fire-resistant finish, enables the effect of the incendiary bomb to be localised after it has penetrated the roof and come to rest on the floor of the loft, attic or upper room. Tests have shown that small incendiary bombs discharged within wooden models of roof spaces spent themselves without the structure catching fire, if it was coated with the new finish. Whether extinction or valuable retardation of fire would occur in practice depends largely upon the size and severity of the bomb. If all exposed woodwork above the wooden floor on which the bomb is stopped and the floor itself are coated to a thickness of an ordinary matchstick—1/16th of an inch—a high degree of retardation of fire caused by small incendiary bombs is assured.

German Naval Plans. (Engineer, Vol. 166, 26th August, 1938, p. 217. Eng. Absts., Vol. 1, No. 9, Section 3, October, 1938, p. 160.) (62/5 Great Britain.)

The limitation to 35 per cent. of surface vessels and 45 per cent. of submarine tonnage built by Britain, agreed to by Germany in the naval treaty, would give her 255,000 tons of battleships, allowing 87,000 tons for aircraft-carriers, 300,000 tons of cruisers and destroyers and 33,700 tons of submarines. At present "Gneisenau" (26,000 tons) is in commission and "Scharnhorst" will shortly be completed. Two 35,000-ton battleships, two aircraft-carriers, three heavy cruisers (of which "Blucher" and "Admiral Hipper" are nearly completed) and two 10,000-ton light cruisers are being constructed. Three 7,000-ton cruisers, sixteen 1,625-ton destroyers and ten 1,811-ton others are projected or commissioned. The German submarines include twenty-four of 250 tons, thirteen of 500 or 700 tons, and thirty-one others, bringing the total ratio up to 45 per cent. Thirteen fast motor-boats are in service and eleven under construction. On completion of this programme it is calculated that she will possess a modern fleet well

adapted to protection of the Reich, maintenance of essential sea-routes and representation abroad.

The Influence of Aircraft on Land Operations. (R. J. Collins, Aeroplane, Vol. 55, No. 1437, 7/12/38, pp. 743-745.) (62/6 Great Britain.)

There are five methods by which aircraft can influence land operations:—

1. Air attack on land forces.
2. Use of aircraft to provide covering fire.
3. Attack on communications.
4. Bombing of headquarters.
5. Transport of troops (including parachute drops).

The author gives examples of each of these methods covering not only the 1914-18 war but also more recent events in Spain, China and Abyssinia.

Although according to the author, the air force is not likely to be able to force a final decision, there is no doubt that the influence of aircraft on land operation is much greater than it was.

Three types of aircraft seem to call for special development.

1. Ground strafing.
2. Long range fighters to accompany bombers.
3. Fast troop transport.

Parachute Troops—Training and Utilisation. (R. Chevalier, Luftwehr, Vol. 5, No. 10, Oct., 1938, pp. 392-398.) (62/7 France.)

The Central Training School for Parachutists is at Pujant-Avignon and the author describes the method of training devised by Major Geille. Over 1,900 jumps have so far been carried out from aircraft without a serious accident. Two types of parachutes are employed: the Irving S.G.P. and the Russian Irvin. The surface of the chute is 58 m.^{2} and the landing speeds vary between 5 and 7 m./sec. The armament of the troops comprises a light machine gun and a 7.5 mm. rifle and is contained in special leather bags strapped to the parachutist. On approaching the ground, the parachutist can release this bundle which falls about 6 m. and is then held by a rope. Thus, on landing, this bundle touches the ground first and slows up the descent. Heavier armament is dropped in containers which are attached to special parachutes. The container weighs 50 kg. and can carry a weight of 150 kg. (either ammunition or special guns up to 37 mm. calibre, etc., mortars up to 81 mm.).

The author gives various examples of the use of parachute troops such as (1) temporary occupation of a sector (2) flank protection (3) pursuit (4) destruction of roads, etc. (5) dropping of intelligence agents. Parachute troops appear to have special possibilities in mountainous country.

Methods of Using Aircraft for Ground Attack. (Luftwehr, Vol. 5, No. 10, Oct., 1938, pp. 399-400.) (62/8 Sweden.)

The various methods such as horizontal high and low altitude bombing and dive bombing are illustrated. Low altitude bombing is carried out between 50 and 500 m. the aircraft flying horizontally at great speed and subjecting the ground to a simultaneous machine gun fire. This method of attack has been used successfully in Spain and can only be carried out against targets weak in A.A. Artillery. If proper use is made of geographical features, darkness, clouds, etc., the risk which the attacking aircraft run is not excessive, especially if a surprise can be effected. Both high and low altitude bombing require fairly extended targets, whilst dive bombing is specially intended to deal with restricted objectives, the accuracy of aim being much greater. Recent improvements in A.A. Artillery have forced the dive bomber to keep above 1,500 m. at release. Even at this height, however, the method presents considerable advantage when used against mobile targets such as ships. The time of drop from 1,500 m. (taking

into account a diving velocity of the aircraft of the order of 550 km./h.) is of the order of 10 sec., which is about $\frac{1}{8}$ of the time required for the bomb to drop from 5,000 m. with the aircraft flying horizontally. There is thus less chance of the ship escaping by altering course.

The Gun Defence of the Bomber. (C. Nikitin, Luftwehr, Vol. 5, No. 10, Oct., 1938, pp. 401-2.) (62/9 U.S.S.R.)

The high altitude bomber is not exposed to much danger by A.A. fire from the ground. The risk of a surprise attack from fighters is, however, considerable. For this reason the utmost attention must be paid to the training of the gunners on the bomber so that they do not allow themselves to be surprised but are ready to repel the fighter as soon as he appears. If the bombers maintain formation so as to have mutual fire support, they have little to fear of a fighter attack. Several cases have occurred in Spain where bombers were shot down over their own territory after returning from a raid. This shows that vigilance must be kept up continuously and not relaxed because an attack is considered improbable. Such attacks are usually carried out by one or other of the following methods:—

(1) The fighter approaches with the sun in his rear.
(2) Attack from a cloud.
(3) Simultaneous attack from several directions.
(4) Attack from the rear, the fighter diving.

The gunner on the bomber must be adequately trained to deal with any of these methods. Both initiative and rapid observation power are required, quite apart from considerable courage. On the proper choice of the gunner will depend the success of the bombing raid.

Organisation of the Italian Air Force. (Luftwehr, Vol. 5, No. 10, Oct., 1938, p. 415.) (62/10 Italy.)

The fundamental unit of the Air Force (armata aerea) is the flight (squadriglia). Several flights form a group (gruppo) whilst a number of groups form an air regiment (stormo). Two combined regiments are called an aerial brigade (brigata aerea), whilst three or more regiments form an aerial division (divisione aerea). Two or more divisions are called an aerial squadron (squadra aerea) and such a squadron would also comprise a variable number of reconnaissance flights. A number of squadrons, divisions and brigades form a large battle unit.

The Italian Air Force consists of 93 groups without counting the units stationed in Africa.

Edge Resistance of Blade Rows. (E. Grunagel, Forschung, Vol. 9, No. 4, July/August, 1938, pp. 187-196.) (62/11 Germany.)

For the determination of the no-load power of turbo-type machines, or of the wheel friction of rotor rims, it is of great importance to know the edge resistance of the blade rows. The present paper reports on experiments with an air passage of rectangular cross-section, the two side walls of which are fitted with blades which could be inclined to any desired angle with the direction of the flow. The edge resistance was found to be essentially dependent on the Reynolds number, the blade angle, the ratio of the width of the passage to the blade pitch, and, in the case of small passage widths, also on the relative displacement of the blade rows.

Calculation of the Chordwise Load Distribution Over Aerofoil with Sections with Plain, Split, or Serially Hinged Trailing Edge Flaps. (H. J. Allen, N.A.C.A. Report No. 634, 1938.) (62/12 U.S.A.)

A method is presented for the rapid calculation of the incremental chordwise normal-force distribution over an aerofoil section due to the deflection of a plain flap or tab, a split flap, or a serially hinged flap. This report is intended as a

supplement to N.A.C.A. Report No. 631, wherein a method is presented for the calculation of the chordwise normal-force distribution over an aerofoil without a flap or, as it may be considered, an aerofoil with flap (or flaps) neutral.

The calculations are made possible through the correlation, by means of thin-aerofoil theory, of numerous experimental normal-force distributions. The method enables the determination of the form and magnitude of the incremental normal-force distribution to be made for an aerofoil-flap combination for which the section characteristics have been determined.

A method is included for the calculation of the flap normal-force and hinge-moment coefficients without necessitating a determination of the normal-force distribution.

A Method of Rapidly Estimating the Position of the Laminar Separation Point. (A. E. von Doenhoff, N.A.C.A. Tech. Note No. 671, 1938.) (62/13 U.S.A.)

A method is described of rapidly estimating the position of the laminar separation point from the given pressure distribution along a body; the method is applicable to a fairly wide variety of cases. The laminar separation point is found by the von Kármán-Millikan method for a series of velocity distributions along a flat plate, which consist of a region of uniform velocity followed by a region of uniformly decreasing velocity. It is shown that such a velocity distribution can frequently replace the actual velocity distribution along a body in so far as the effects on laminar separation are concerned.

An example of the application of the method is given by using it to calculate the position of the laminar separation point on the N.A.C.A. 0012 aerofoil section at zero lift. The agreement between the position of the separation point calculated according to the present method and that found from more elaborate computations is very good.

Flow Observations with Tufts and Lampblack of the Stalling of Four Typical Aerofoil Sections in the N.A.C.A. Variable Density Tunnel. (I. H. Abbott and A. Sherman, N.A.C.A. Tech. Note No. 672, 1938.) (62/14 U.S.A.)

A preliminary investigation of the stalling processes of four typical aerofoil sections was made over the critical range of the Reynolds number. Motion pictures were taken of the movements of small silk tufts on the aerofoil surface as the angle of attack increased through a range of angles including the stall. The boundary-layer flow at certain angles of attack was also indicated by the patterns formed by a suspension of lampblack in oil brushed on to the aerofoil surface. These observations were analysed together with corresponding force-test measurements to derive a picture of the stalling processes of aerofoils.

The final flow break down occurs either as leading edge separation (laminar boundary layer separates and failure to re-establish the flow through the formation of turbulence) or as separation of the turbulent boundary layer near the trailing edge.

These two stalling processes are not separate phenomena but are intimately related, the actual point of separation being influenced by the general boundary layer conditions. The tufts often failed to show local separation indicated by the lampblack and it seems, therefore, that the region of reversed flow may be very shallow and have little effect on the general flow.

Further studies of the flow changes and force fluctuations at the stall are required as well as the effects of scale and turbulence and type of stall on the performance of the aircraft in general.

The Approximate Prediction of Skin Friction and Lift. (N. A. V. Piercy, J. H. Preston and L. G. Whitehead, Phil. Mag., Vol. 26, No. 178, Nov., 1938, pp. 791-815.) (62/15 Great Britain.)

The method of successive approximation previously developed for the flat plate case of skin friction with laminar flow can be generalised to yield a close approxima-

tion to that round the contours of cylinders appropriate to any analytical assumption regarding the irrotational flow outside their boundary layers. Computation is almost eliminated till the stage is reached when mathematical errors become small. A simple third approximation to the solution of the boundary layer equations suffices for many purposes until breakaway is approached. Explicit approximate formulæ follow for the position of breakaway and for the skin friction of elliptic cylinders. Regarding the external flow, an appropriate assumption is obtained by recognising the existence of a wake to the extent of elongating the cylindrical boundary from the points of breakaway to infinity. A rapidly convergent method of successive approximation is developed for its application. Any reasonable assumption regarding the thickness and configuration of this rudimentary wake secures, it appears, much closer agreement with experiment than has so far been possible by ignoring the wake. Determining the circulation round a lifting cylinder from considerations relating to the artificial wake rather than to the points of breakaway considerably decreases earlier divergence from experiment. As an illustration, the variation of lift with inclination of section is calculated from first principles for a given elliptic cylinder, and the result is found to agree fairly with experiment, the "stall," in particular, being predicted with some accuracy.

Compared with earlier methods, those now advanced promise improved physical accuracy in predictions of skin friction, breakaway lift, and stall which make no appeal to experimental data. Their analytical convenience will, it is hoped, facilitate investigations of associated problems for which an exceptional degree of mathematical accuracy may not be required.

Oscillatory Motion of a Fluid Along a Circular Tube. (D. G. Chrostopherson, A. Gemant, A. H. A. Hogg and R. V. Southwell, Proc. Roy. Soc., Series A, Vol. 168, No. 934, 7/11/38, pp. 351-78.) (62/16 Great Britain.)

This paper is concerned with oscillatory motion (either free or forced) of a viscous fluid along a circular tube: the restoring force comes in both instances from the "gravity head" which results from the passage of fluid. Part I is a theoretical discussion of the problem. Part II deals from a practical standpoint with complicating factors (e.g., turbulence, or meniscus and other end effects) which the theory does not take into account, and briefly discusses a possible application to viscometry. Part III gives the results of experiments made to test the predictions of Parts I and II.

Supersonic Flow Over an Inclined Body of Revolution. (Hsue-Shen-Tsien, J. Aer. Sci., Vol. 5, No. 12, Oct., 1938, pp. 480-3.) (62/17 U.S.A.)

A first approximation is obtained for the side force or the lift of a body of revolution inclined in a supersonic flow from the linearised equation of motion of compressible fluids. It is shown that the lift at any fixed Mach's number is directly proportional to the angle of attack of the body. The case of the cone is calculated in detail and a general method using step-wise doublet distribution is developed for a pointed projectile.

The Influence of Lateral Stability on Disturbed Motions of an Aeroplane with Special Reference to the Motions Produced by Gusts. (R. T. Jones, N.A.C.A. Report No. 638, 1938.) (62/18 U.S.A.)

Disturbed lateral motions have been calculated for a hypothetical small aeroplane with various modifications of fin area and dihedral setting. Special combinations of disturbing factors to simulate gusts are considered and the influence of lateral stability on the motions is discussed.

The modifications of the aeroplane include changes of dihedral from 0° to 10° and changes of the weathercock stability from zero to $C_n = 0.137$ (the equivalent of a fin as large as 10 per cent. of the wing area). The positions of the modified aeroplanes on the lateral stability charts are shown.

Fin area and wing dihedral were found to be of primary importance in side gusts. It was found that the rolling action of the wing with as much as 5° dihedral was distinctly unfavourable, especially when the weathercock stability was small. A study of the effects of gusts gives different indications depending on the interval of time considered. During the first stages, the upsetting movements of the stable aeroplane may be more severe than those of a slightly unstable one. If the aeroplane is under control and if the gusts are of noticeable magnitude, then the motion during the first 2 or 3 seconds is of primary concern. For uncontrolled flight or for flight in relatively calm air where disturbances could become apparent only through introducing a divergence, the later stages of the motion are of interest.

The damping of rolling is such that the aeroplane very quickly takes on any rolling component of gust velocity.

The Drag of Inflatable Rubber De-icers. (R. G. Robinson, N.A.C.A. Tech. Note No. 669, 1938.) (62/19 U.S.A.)

Force tests on rubber de-icer models of several different profiles at approximately 1/3 full scale were carried out in the N.A.C.A. eight-foot high speed wind tunnel. The experiments lead to the following conclusions:—

(1) Drag additions caused by a normal deflated de-icer were from 13 to 29 per cent. of the smooth-wing drag, depending on the speed and attitude of the wing.

(2) For the inflated conditions, the drag additions were of the order of 100 per cent. of the smooth-wing drag.

(3) Beneficial results were obtained both by eliminating the irregularities of the deflated de-icer surface and by making the attaching fittings as nearly flush as possible. The drag additions were then from 1 to 19 per cent.

(4) Fluttering and bulging of rubber de-icers were experienced when they were subjected to negative pressures of the order of 60 pounds per square foot. The critical speed was raised as much as 100 miles per hour by increasing the tension in the rubber and backing the rubber with fabric.

On the Correction to be Applied to the Measured Take-off Run so as to Eliminate Differences Due to Pilotage. (H. Kimura, Aer. Res. Inst., Tokio, Report No. 169, September, 1938.) (62/20 Japan.)

The take-off run of an aircraft depends very markedly on the speed at take-off. Since personal difference of pilotage is unavoidable, the length of run, even when corrected for wind and reduced to standard air conditions, is variable and extrapolation to overload conditions is thus uncertain.

The author proposes the following method of overcoming this difficulty.

(1) The take-off speeds, corrected for wind are plotted against the weight and a mean curve drawn.

(2) The variation ΔS in take-off runs due to a variation ΔV from the mean speed is measured or calculated assuming constant incidence.

(3) The take-off run corresponding to the mean take-off speed is then plotted against weight and the resultant curve extrapolated to overload conditions.

The method was applied successfully to the Japanese long range aircraft Koken. The author also discusses the effect of wind on the length of take-off runs.

If S_0 = take-off run with no wind,
S_1 = take-off run into a wind velocity V_1,
t_1 = take-off time at a wind v_1
$(S)_{0\to v1}$ = distance required to attain a speed v_1,

Then $S_0 = S_1 + v_1 t_1 + (S_0)_{0\to v1}$

The author shows how the factor $(S_0)_{0\to v1}$ (which is often neglected) can be obtained in a simple manner.

Estimation of Wing Weights. (J. E. Lipp, J. Aer. Sci., Vol. 5, No. 12, Oct., 1938, pp. 491-3.) (62/21 U.S.A.)

A method for making preliminary estimates of wing weights is described. Equations are given to show the manner in which spar cap, spar web, rib, and miscellaneous weights vary with the dimensions of the aeroplane.

Some Aerodynamic Problems in the Design of the Convertible Aeroplane. (G. P. Herrick, J. Aer. Sci., Vol. 5, No. 12, Oct., 1938, pp. 494-7.) (62/22 U.S.A.)

The main feature of this paper lies in the fact that, up to July 30, 1937, heavier-than-air machines could be divided into two general classes. In the first class were the aeroplanes with their refinements and improvements for efficiency and speed. In the second class were the rotor-planes with their special characteristics of jump-off, hovering, high-angle and vertical take-off, and landing.

On July 30, 1937, a convertible aeroplane took off and landed as an aeroplane, did likewise as a rotor-plane, and then took off and flew as an aeroplane or machine of the first class mentioned, and, at 1,700ft. released and started its upper wing in rotation, landing as a rotor-plane, or machine of the second class mentioned. This might be regarded as demonstrating a new class, the convertible, a combination of both aeroplane and rotor-plane.

Conversion of the convertaplane was accomplished by releasing and starting the upper wing rotating and by control of its unbalanced moments, occasioned by the differential in lift between the advancing and receding blades of the rotor-wing.

Some Details on the Italian Altitude Record. (Les Ailes, No. 910, 24/11/38, p. 8.) (62/23 Italy.)

The Caproni aircraft which reached an altitude of 17,100 metres weighed 1,690 kg. No details are given with regard to the engine, a 14-cylinder twin row Piaggio. Marelli magnetos and sparking plugs were fitted, preliminary researches having revealed methods for overcoming high tension leakage in the stratosphere.

A 4-blade wooden airscrew of large blade area was used on account of its low weight, although the fixed pitch made the take-off difficult. The cabin is in the form of a metallic cylinder surmounted by a hemispherical cupola fitted with windows. The pilot was supplied with an oxygen mask and sealed the cabin at 8,000 m. The cabin thus had only to withstand the pressure differences between this altitude and the ceiling, approximately 200 mm. of mercury. The air in the cabin is circulated by means of a pump, the excess moisture and CO_2 being extracted.

It is stated that the stuffing boxes through which the engine and aircraft controls pass gave considerable trouble before they could be made reasonably airtight.

Methods of Aircraft Production in U.S.A. (T. P. Wright, Airc. Eng., Vol. 10, No. 118, Dec., 1938, pp. 386-409.) (62/24 U.S.A.)

In this well illustrated article (119 figures) the author describes the general production method of leading American aircraft firms.

Although great strides have been made in the construction of quality and quantity production, the following improvements are suggested:—

(*a*) Greater shop experience for drafting personnel.
(*b*) Standardisation of best method of wing construction.
(*c*) Study of stainless steel and spot welding.
(*d*) Development of riveting tools.

Whilst the methods of fuselage, tail and control surface construction are not likely to change in the near future, wing construction is still in a state of flux and the design adopted by various firms differs appreciably.

Engine mountings of welded chrome molybdenum steel are fairly general and riveted fuel tanks (using synthetic rubber as a leak preventative) are likely to be used more extensively in the future.

It is interesting to note that the relative cost of the assembly constituents of aircraft have not changed very much over the last 10 years. This is shown in the following table:—

	1929	1938
Wing Group	29	32
Tail Group	7	6.5
Fuselage	18.5	13.5
Landing Gear	7	15.5
Power Plant	15	16.0
Equipment	12.5	8.0
Armament	3.5	3.0
Assembly	7.5	5.5
	100.0	100.0

The 1929 construction is a tube fuselage, wooden beam biplane, fabric covered with fixed landing gear. The 1938 product is a stressed skin all-metal monoplane with retractable landing gear. The extra cost of this gear represents the main difference.

Increase in the Speed of Aircraft During Recent Times. (E. Heinkel, General Meeting Lilienthal Society, Berlin, Oct. 12, 1938. Translation No. 766.) (62/25 Germany.)

The maximum speed of a single seat fighter has increased from 250 km./h. (1921) to 700 km./h. in 1938. Of this speed increase 300 km./h. are due to aerodynamic improvement of the aircraft structure, and 150 km./h. to increased engine performance (supercharging).

The supercharged engine gives a poor ground performance unless variable pitch propellers are fitted. Even then it may be necessary to fit a variable speed gear between engine and propeller in order to obtain the necessary thrust at take-off. The high flying speeds also affect the propeller efficiency (compressibility of the air). The velocity of sound at the ground is 1,230 km./h. and falls off to 1,060 km./h. at an altitude of 11,000 m. Since the resistance increases rapidly as the speed approaches the velocity of sound, the most efficient altitude decreases with increase in flying speed above 650 km./h. The author is of the opinion that a speed of the order of 1,000 km./h. near ground level will present the ultimate possible limit. Of interest is the effect of armament on maximum speed. External machine gun emplacements such as were employed in the 1914-18 war would cause a speed reduction of nearly 70 km./h. in the case of a modern bomber capable of doing 500 km./h. without excrescences. By suitable fairing this drop can be reduced to something of the order of 10-20 km./h. in modern installations.

Studying Engine Combustion by Physical Methods. (I. Withrow and G. M. Rossweiler, J. Applied Physics, Vol. 9, June, 1938, pp. 362-72. Fuel, Vol. 17, No. 11, Nov., 1938, p. 348.) (62/26 U.S.A.)

The author reviews the various physical methods that are being used for the study of combustion in an internal combustion engine. The latest development of high-speed cinematography is described and, as a typical result, 24 successive pictures of the propagation of an explosion over 43 crankshaft deg. are shown. Typical emission spectra are shown, those in the flame-front being contrasted with those in the afterglow and those in a bunsen flame. Temperature measurements determined by the sodium-line reversal method show a temperature of 2,000°C. at the beginning of combustion, 10 deg. after ignition, and 2,400°C. on completion

of combustion 45 deg. after ignition. Time displacement photographs which show pressure waves in the inflamed charge are shown. Absorption spectra are given for knocking and non-knocking conditions.

Spectroscopical Investigation of the Process of Combustion in Internal Combustion Engines. (E. Czerlinski and M. Seibt, L.F.F., Vol. 15, No. 6, 6/6/38, pp. 316-20. Fuel, Vol. 17, No. 11, Nov., 1938, pp. 348-9.) (62/27 Germany.)

The facts brought to light by spectroscopical investigations of the process of combustion in internal combustion engines are discussed. As an aid to the interpretation of the reported phenomena, the results of spectroscopical research on open flames are referred to. The experiments that have proved most productive in yielding information have been those conducted with a carburettor engine in the visible and the ultra-violet regions. It has been established that a narrowly defined flame front emits characteristic bands which in the case of normal combustion correspond to the spectrum of the inner cone of the Bunsen-burner flame. The carriers are the dicarbon CC, methane CH, and hydroxyl OH. In an engine producing the phenomenon of knock, the bands of the radicals CC and CH in the flame front disappear at the instant of setting in of the knock. The admixture of anti-knock agents not only restores the normality of the pressures, but the spectral emissions also provide evidence of normal combustion. The presence of formaldehyde ahead of the flame front is manifested only in the case of knock, and at no other time. The chemical process in the mechanism of combustion with knock pursues a different course from that followed in normal combustion. The discussion is illustrated by spectrograms showing the effects of different conditions and the influence of detonation-inhibiting agents.

Aircraft Fuels (42 *References*). (S. D. Heron and H. A. Beatty, J. Aer. Sci., Vol. 5, No. 12, October, 1938, pages 463-79.) (62/28 U.S.A.)

Experience in the United States show that the safest fuels for general service are those whose octane numbers are least subject to change with engine test conditions. Thus, straight-run petrols or their blends with branched chain paraffins are much less open to doubt than petrol blends with aromatics, alcohols, or olefins. Any fuel which shows the characteristic of a falling octane number with increase of speed, cylinder temperature, or mixture temperature in knock testing may be subject to doubts as to its full-scale reliability. These views are not accepted in Europe and other parts of the world, and change of engine type in the United States may cause modification.

By and large, in the light of present knowledge, straight-run petrols (or synthetic petrols of similar properties) and branched-chain paraffins are the outstandingly useful aviation fuels. They are stable in storage, have very low water solubility, give the highest heating values, and their octane numbers are subject to only a slight variation with engine type or operating conditions.

While the anti-knock properties of the water-soluble fuels such as alcohols and ketones may appear attractive, such fuels are less desirable than hydrocarbons for general service use. In some types of operation, however, take-off output and fuel availability may be more important than range, and in such cases oxygenated fuels may find a field of application, in spite of their inherent danger of water separation.

Evaporation and Knock Rating of Motor Fuels. (O. Herstad, Oelu. Kohle, Vol. 14, 1938, pp. 657-60. J. Sci. Chem. Ind. (Abstracts B), Vol. 57, No. 11, Nov., 1938, p. 1256.) (62/29 Germany.)

The time of evaporation (y) of drops of org. liquids is related to the wt. of the drops (x) by $y=cx^m$, where c is a constant and m has the value 1.65—1.78 for evaporation in the ordinary state and 2.5—2.9 for that in the " transformed " (spheroidal) state. The bearing of the results on the behaviour of drops of motor

spirit in the cylinder of the internal-combustion engine is discussed. The rate of evaporation of very small drops has been studied under the microscope; as the drop diminishes in size the evaporation may pass from the normal type through a labile state to the " transformed " type. It is suggested that the ultimate rate of evaporation of very small drops can be related to mol. velocities as calc. from the kinetic theory.

Behaviour of Diesel Fuels at Low Temperatures. I—Influence of Temperature of Suction Air and Cylinder Walls on Critical Compression Ratio. II—Influence of Low Temperature on Flow of Diesel Fuels Through Bosch Filters. (L. Rosenfeld, Petrol Times, Vol. 39, 1938, pp. 593-5 and 627-9. J. Soc. Chem. Ind. (Abstracts B), Vol. 57, No. 11, Nov., 1938. p. 1256.) (62/30 U.S.A.)

I. Six petroleum fuels of cetane nos. ranging from 44.5 to 65.5 were tested in a C.F.R. single-cylinder engine with direct ignition head. The suction air was cooled to $-30°$ and various cylinder temperatures were maintained by means of cooling fluids, e.g., MeOH. The critical compression ratio increased with rise in temperature. Changes in the temperature of the suction air or cooling liquid produced about the same effect. The cetane number of the fuel gave no indication of its ignition quality under changed temperature conditions.

II. The filterabilities at $-100°$ of normal gas oil, oil filtered once at room temperature, and oil freed from asphaltic matter by acid treatment were compared. The data show that impurities alone caused pumping difficulties. Asphaltic matter and high η due to low temperature did not cause choking of the filter.

Changes Occurring in Lubricating Oils in Internal Combustion Engines. (H. Weiss and A. Maillard, J. Inst. Petroleum Tech., Vol. 24, 1938, pp. 407-20.) (62/31 U.S.A.)

Experiments with oils in Diesel and spark-ignition engines indicate that the increase of d, η, acidity, ash and the quantity of oxidation products precipitable by light naphtha is very regular. Of these products that portion insoluble in $CHCl_3$ is the most important for it is also insoluble in hot oil. It is shown that this insoluble portion is not always soot. Pyrolysis does not appear to be likely with mineral oil; experiments show that it does not occur with mineral oil until 360° is reached, though with castor and olive oils the temperature is 250° and 310°, respectively. Unburnt or partly burnt fuel does not seriously increase sludge, which latter is mainly the outcome of oil oxidation. Tests by which it is hoped to recreate the reactions of oil in engine service are described.

The Behaviour of Compressed Gas in Steel Flasks. (J. H. Brunklaus, Gas u. Wasserfach, Vol. 81, 1938, pp. 696-8. Chem. Absts., Vol. 32, No. 22, 20/11/38, p. 9445.) (62/32 U.S.A.)

When a steel cylinder filled with coal gas under high pressure was discharged it was found that the liquid light oil present in the cylinder served as a solvent for gas constituents such as H, CH_4, etc., and that these gases carried light oil in the form of a fog, which was vapourised, enriching the gas. Light petrol is a better solvent for CH_4 than is propane or butane. These observations are of special value for automotive operation with compressed gases.

The Differential Analyser and its Applications in Electrical Engineering. (D. R. Hartree and A. K. Nuttall, J. Inst. Elec. Eng., Vol. 83, No. 503, Nov., 1938, pp. 643-7.) (62/33 Great Britain.)

The present paper describes the mathematical principles underlying the solution of differential equations by means of the differential analyser. A brief description of the principal mechanical features of the machine is given, and the method of operation is outlined. The paper reviews a number of problems which have been

investigated by means of the differential analyser, and indicates further problems which appear to lend themselves to this method of attack.

Measuring Instruments. (R. M. Archer, Electrician, 28/10/38, pp. 497-9. Metropolitan Vickers Tech. News Bulletin, No. 633, 4/11/38, p. 5.) (62/34 Great Britain.)

This article which deals with the more notable developments in measuring instruments during the past year is supplemented by descriptions of new meters and instruments on pp. 500-511 of this issue. The products described include: galvanometers having high sensitivity, indicators, test sets, oscillographs recorders, remote indicators, meter testing transformers, photometric and acoustical apparatus, and recent laboratory and radio-frequency instruments. Illustrated with seven photographs and one oscillogram.

Optical Inspection in the Metal Industries. (H. Dunlein, Eng. Prog., Oct., 1938, pp. 189-93. Metropolitan Vickers Tech. News Bulletin, No. 633, 4/11/38, p. 11.) (62/35 Great Britain.)

This article describes various types of optical apparatus produced by Carl Zeiss for the examination of materials and machine parts (greatly varying in form and size), for slag inclusions, porosity, the fineness of machined surfaces and similar conditions. Arrangements are made for the viewing of an object in a bright field, dark field, or under polarised light and also for the projection of the image on to a photographic plate. The author concludes by describing and outlining the advantages of apparatus applying the principles of spectrum analysis and photometry to the qualitative and quantitative analysis of materials. Illustrated with 11 photographs.

Bronzavia Tail Drift Sight. (H. A. Taylor, Flight, Volume 34, No. 1563, 8th December, 1938, pp. 534-5.) (62/36 France.)

This new sight is of the periscope type and has a specially controlled sighting bubble. In ordinary use, the ground object is followed on the bubble down a grid wire and a special stop watch arrangement enables the speed of the machine to be read off if the altitude is known. The hand of the watch stops automatically after the prism has been turned through a certain angle.

Pressure Responsive Elements. (P. G. Exline, Transactions (A.S.M.E.), Vol. 60, No. 8, Nov., 1938, pp. 625-32.) (62/37 U.S.A.)

Pressure-responsive elements commonly used in indicating and recording instruments are manometers, free piston gauges, Bourdon tubes, diaphragms, and bellows. The mathematics of the primary elements, manometers, and free piston gauges is simple and direct. Analyses of Bourdon tubes and diaphragms show that predictions of their performance curves are not amenable to precise calculation even under the simplest conditions, which conditions do not generally obtain in instruments. Generally, the instrument maker must rely upon empirical knowledge, coupled with approximate calculations, for design data. Linkage adjustments must be provided to correct for variations in dimensions and materials normally encountered in manufacture.

Emphasis is placed on the usefulness of bellows as pressure elements, and approximate formulæ for calculating their behaviour are given. The results of considerable experimental work on the characteristics of bellows of various sizes and materials show that in many cases they are ideal elements for pressure-responsive instruments. An example of such use in a special duty pressure gauge is given.

Pressure-Type Thermometer Systems. (L. G. Bean, Transactions (A.S.M.E.), Vol. 60, No. 8, Nov., 1938, pp. 657-63.) (62/38 U.S.A.)

This paper, which deals exclusively with the common forms of industrial temperature-measuring systems working on a pressure principle, analyses the essential elements of a basic pressure-type system with reference to the design problems involved and describes various typical instruments in the conventional classifications in order to illustrate the development of these thermometer systems into reliable instruments for commercial measurements. Included in these classifications are liquid-filled, vapour-tension, and gas-filled thermometers, all of which are described and illustrated.

New Automatic Direction Finder. (*Sperry—R.C.A.*) (American Aviation, Vol. 2, No. 11, 1/11/38, p. 17.) (62/39 U.S.A.)

According to the manufacture, the Sperry—R.C.A. radio automatic direction finder requires only that the pilot tune to a station. The pointer on the instrument has an arrow at one end and indicates the exact bearing of the station. A great advantage consists in the fact that this bearing is held up to the point of passing over the station. Positive information is thus available to confirm the " cone of silence " if the pilot has been flying on the regular radio beam. This cone by itself is unsatisfactory because it only corresponds to a momentary complete absence of any signal. The instrument will also be very useful as an auxiliary or checking device on other methods of position finding. It is stated that it can be worked successfully under conditions of " static " which rule out all null methods by hand operated loop.

Torsional Fatigue Strength of Beryllium-Nickel and Beryllium-Contracid Spring Wire at Temperatures up to 300°C. (W. Hellwig, Forschung. Vol. 9, No. 4, July-August, 1938, pp. 165-176.) (62/40 Germany.)

The tests were carried out on straight pieces of cylindrical wire, special attention being paid to the method of clamping. The fatigue tests were carried out both with and without previous static loading and demonstrated the superiority of the alloy wires to the best steel samples. Thus the working capacity of a beryllium-nickel spiral spring is at least 30 per cent. greater than that of a steel spring of the same dimensions. It should be noted that other advantages of the alloy are its freedom from rust and stability in sea water. Good results can, however, only be obtained if special attention is paid to the heat treatment of the alloy prior to use.

Transverse Oscillations of Flywheels. (G. Heinrich, Forschung, Vol. 9, No. 4, July-August, 1938, pp. 177-186.) (62/41 Germany.)

A flywheel situated between two cranks displaced by 120° showed marked transverse oscillation at certain r.p.m. The author investigates this effect mathematically and develops a method for determining critical speeds. It appears that resonance is generally only possible if pronounced higher harmonics are present in the forcing torque.

Calculation of Stresses in Revolving Flywheels, Belt and Rope Pulleys. (W. Heusinger, Forschung, Vol. 9, No. 4, July-August, 1938, pp. 197-208.) (62/42 Germany.)

The calculation of the stresses in flywheels and similar elements has not received much attention in scientific literature. In order to simplify the calculations, certain factors are usually neglected (often without sufficient justification), as the procedure becomes otherwise too complicated for practical application. The author develops an accurate and strictly scientific method of calculation which meets the designer's requirement as to simplicity both in respect of the development of the formulæ and of their application to practical cases.

The Relations Between the Energy Theorems Applicable in Structural Theory. (D. Williams, Phil. Mag., Vol. 26, No. 177, Nov., 1938, pp. 617-35.) (62/43 Great Britain.)

The following theorems are discussed:—

(A) Theorem of Virtual Work.

(B) Theorem of Minimum Potential Energy.

(C) Castigliano's Theorem of the Differential Coefficients of the Internal Work (Parts I and II).

(D) Castigliano's Theorem of Least Work (called by Southwell The Second Theorem of Minimum Strain Energy.)

(E) Statical analogue of Bertrand's Theorem in Dynamics, alternatively, The Theorem of Maximum Strain Energy.

(F) Statical analogue of Kelvin's Theorem in Dynamics (called by Southwell The First Theorem of Minimum Strain Energy).

It is shown that Theorems (A) (B) and Part I of (C) are in their application to structural problems fundamentally identical, and capable of general application in that they are true whatever the law connecting load and deformation may be. Part II of (C) is based on Part I and on the assumption that the total strain energy is equal to half the sum of the products of the external forces and their respective displacements. As the latter assumption is only valid for structures that obey Hooke's law, Part II of (C) is only true when this law is satisfied.

Theorem (D) is deducible directly from Part II of (C) and is, therefore, subject to the same limitation. In this way Theorems (B) and (D) may be regarded as the first and last links in a chain of interrelated theorems. At this stage in the argument the two Theorems (B) and (D) are directly compared, and the essential features that distinguish the one from the other are analysed. Their relative usefulness in the solution of structural problems is also discussed.

Theorems (E) and (F) are next considered and the relevant proofs are included in the appendix, chiefly because they appear never to be given fully except in their dynamical form. The validity of both theorems is dependent on the operation of Hooke's law. Theorem (E) is next enunciated in a new form, and so shown (in the appendix) to be directly related to Theorem (B) in fact to be merely a particular case of that theorem. The physical connection between Theorems (E) and (F) is then explained and their relative usefulness discussed.

Stainless Steel Welding. (V. W. Witmer, Sheet Met. Ind., Nov., 1938, pp. 1299-1302. Metropolitan Vickers Tech. News Bulletin, No. 634, 11/11/38, p. 5.) (62/44 Great Britain.)

The author examines the welding properties of chromium steels and nickel-chromium steels. The former is shown to give a brittle weld which can be partly improved by heat treatment, whilst the latter, although giving a tough weld, gives rise to difficulties due to its large coefficient of expansion. The above are considered in relation to electric arc welding, but projection, seam and flash welding of stainless steels with a choice of electrodes are also reviewed.

Illustrated with four photographs.

The Working of Stainless Steels. (Machinist L., 5/11/38, pp. 869-80. Metropolitan Vickers Tech. News Bulletin No. 634, 11/11/38, p. 8.) (62/45 Great Britain.)

Particulars are given of the composition of stainless steels together with a list showing the corrosive resistance of various steels to different acids and salts. Machining of the alloys is discussed as well as the tools required for particular steels, followed by a description of polishing and grinding methods now in use. After explaining how stainless steels can be cold worked, a list of their various mechanical properties is given and a description of the design and use of welded

joints with stainless steels. Finally, modern methods of annealing chrome stainless steels are explained.

Illustrated with four diagrams and three tables.

Fatigue and Corrosion Fatigue of Steels. (B. B. Wescott, Mech. Engineering, Nov., 1938, pp. 813-822. Metropolitan Vickers Technical News Bulletin No. 634, p. 13.) (62/46 Great Britain.)

The author points out the present-day need for knowledge in this field and then discusses various results obtained by the machine developed by R. R. Moore. He then discusses various formulæ for the range of stress to be safely applied and continues by describing the nature of fatigue failure and shows how different forms of heat treatment can alter the fatigue limit. He concludes the article by first showing how tests were made with notched and corroded specimens and the results deduced from these, also the effect of damping capacity on fatigue strength. Illustrated with four photographs, 14 diagrams and four tables.

Magnetic Crack Detecting on Turbine Blades and Rotors. (T. C. Rathbone, Power, Nov., 1938, pp. 74-7. Metropolitan Vickers Technical News Bulletin No. 635, 18/11/38, p. 5.) (62/47 U.S.A.)

The author discusses the earlier methods for crack testing in the case of both assembled and unassembled blades, and points out the advantages of a powder called magnaflux used for this purpose. This consists of iron particles coated with an inert oxide and capable of passing through a hundred mesh. The powder is used dry and therefore cleaning of large turbine shaft assemblies is simplified, though the real difficulty is to ensure proper magnetisation. Photographs showing typical examples and methods of magnetising blades and turbine shaft assemblies are given. Illustrated with five photographs.

Testing Tensile Strength of Deposited Weld Metal. (J. Sack, Phillips' Tech. Rev., Sept., 1938, pp. 279-82. Metropolitan Vickers Tech. News Bulletin No. 632, 28/10/38, p. 6.) (62/48 Great Britain.)

In this article it is shown that it is no longer correct to require in specifications an upper limit for the tensile strength of deposited weld metal. This requirement originated from an assumed relation between the variation with composition of the tensile strength and the brittleness of the material. The relation is stated to be valid for ordinary carbon steels such as have long been used, but no longer holds for modern welding materials. If this stipulation is made it leads to the use of welding rods of poorer quality than would be used if the obsolete requirement were omitted. Illustrated with two diagrams and four tables.

Alloys for Springs. (L. L. Stott and R. W. Carson, Met. Ind., 21/10/38, pp. 395-7. (Metropolitan Vickers Tech. News Bulletin No. 632, 28/10/38, p.9.) (62/49 Great Britain.)

It is shown that the retention of " springiness " in a material under service loads depends on the material's resistance to drift or creep at low temperatures. The drift measurements reported here show that a salt bath heat treatment at 650°F. for 20 minutes, gives minimum drift in cold-rolled beryllium copper strip. Spring temper phosphor bronze was found to have 2.8 times as much drift as beryllium copper and nickel silver 1.4 times as much as beryllium copper when heat treated as above. Illustrated with five diagrams.

Synthetic Resin Moulded Material for Guide Ways on Heavy Machine Tools. (H. Ragotzi, Maschinenbau, Oct., 1938, p. 525. Metropolitan Vickers Tech. News Bulletin No. 632, 28/10/38, p. 12.) (62/50 Germany.)

The author describes experiments carried out by Fried. Krupp A.G. with the object of protecting the guide ways on heavy machine tools. Bronze sheets were

originally used, but were later replaced by synthetic resin boards which gave satisfactory results. Hints are given as to the installation of the latter. Illustrated with two diagrams.

Applying Heavy Metal Deposits. (Electrical Review, 28/10/1938, p. 623. Metropolitan Vickers Tech. News Bulletin No. 633, 4/11/38, p. 10.) (62/51 Great Britain.)

Some details are given of the Fescol method for the salvage of parts that have become worn in use, the rectification of machine shop errors, securing of protection against corrosion, and the improvement of surface quality by the application of heavy metal deposits. One interesting feature is the conversion of the supply from single phase to three-phase by the multi-capacitor pilot motor system devised by the B.T.H. Co. Illustrated with three photographs.

Frettage Corrosion. (Autom. Eng., Vol. 28, August, 1938, p. 278. Eng. Absts., Vol. 1, No. 9, Section 3, October, 1938, p. 153.) (62/52 Great Britain.)

With dry metal surfaces (*e.g.*, splined hubs of gears, fitted bolts, ball races, flanges, propeller shafts and housings) fine Fe_2O_3 dust is formed when the mating surfaces are subject to vibration, if one of the parts is ferrous; this will occur even in what is normally regarded as a tight fit. The rapidity of the action, and consequently the amount of debris, is proportional to the amplitude of relative motion, but independent of both speed and load. Stainless steels and hard steels show the maximum effect, but soft metals are more liable to seize and show less corrosion; the minimum occurs when brass forms one of the pair. Even in contact with glass or wood, steel shows the phenomenon. Lubrication reduces its intensity and in rotational motion it does not occur—apparently under vibration the oil film breaks down. An apparatus for investigating the phenomenon is described, using lapped specimens with a convex and flat face respectively to keep the contact area small. A lateral oscillation is imparted to one by a cam, under any desired load; the outer end of the arm allows the amplitude of vibration to be observed with a micrometer. It appears that minimum frettage occurs with a maximum difference in hardness between the pair of metals.

New Method of Metal Spraying. (The Engineer, Vol. 166, 16th September, 1938, p. 318. Eng. Absts., Vol. 1, No. 9, Section 3, October, 1938, p. 153.) (62/53 Great Britain.)

The process depends on a Swiss " Schori " patent in which the powdered metal is sucked into a stream of compressed air, avoiding the packing which occurs when pressure is used. Interesting applications of the process are the spraying of tanks, hulls, bridges, machinery, aluminium seaplane floats (with Al, Zn or Cd), ammunition, mines and shells (in which it acts as a lubricant in the rifling). The coating can be hammered, riveted or bent without injury, and a patent is being taken out for a (metal and glass) mixture which forms a fusible slag, and a similar mixture with Al base is suitable for protection of iron exposed to high temperature.

Crankshaft and Cylinder Materials. (Autom. Eng., Vol. 28, p. 217. Eng. Absts., Vol. 1, No. 9, Section 3, October, 1938, p. 163.) (62/54 Great Britain.)

The author reports tests on " wet " liners in a wide variety of materials, ranging from English and French nitrided cast iron (reputed 900 Brinell), through heat treated and untreated Ni-Cr-Mo cast iron, chill cast iron with varying quantities of Ni and Cr, centrifugally cast soft iron, a Ni cast iron, electric furnace iron, 35 per cent. Cr iron and other irons, to common cast iron. Recently thin " dry " nitrided liners of 1,000 Brinell have been developed. Oxy-acetylene

hardening for crankshafts is being displaced by induction heating to eliminate the human factor. With h.f. (2,000 cycles) owing to skin effect, heating is mainly superficial and in 4.5 sec. the steel is at hardening temperature to a depth of $\frac{1}{8}$in. Current is then turned off and the article quenched by water spray; some heat is also conducted to the core. File hardness can almost be attained and, apart from conduction, no heat is applied to any part other than the bearing surfaces. The whole crankshaft is then slightly tempered to remove internal stresses. The process confers a hardness greater than any other except nitriding; the core remains strong and such crankshafts last much longer in service than untreated crankshafts.

Stresses and Deformations in Pipe Flanges Subjected to Creep at High Temperatures. (J. Marin, J. Frank. Inst., Vol. 226, No. 5, Nov., 1938, pp. 645-7.) (62/55 U.S.A.)

Various methods have been employed for determining the stresses in pipe flanges using the theory of elasticity (I). There are many cases, however, of pipe flanges which are subjected to stresses and at the same time a high temperature such that creep occurs. This paper gives an analysis of the stresses and deformations produced in a circular ring of rectangular cross section subjected to twisting couples uniformly distributed along its centre line. Such a solution will also give an approximate analysis of the pipe flange. This approximation is justified in view of the complexity of the problem and the uncertainties still present in the fundamental creep-stress relation for metals. In the solution of this problem a deflection theory is also developed for straight beams subjected to bending accompanied by creep.

Methods and Means for Determining the Natural Modes of Vibration of Mechanical Structures. (H. C. Hayes and E. Klein, J. Am. Soc. Nav. Eng., Vol. 50, No. 4, Nov., 1938, pp. 519-26.) (62/56 U.S.A.)

Cyclic strains in vibrating mechanical structures often lead to failures because of the resulting fatigue of the material. Both theory and practice indicate that the breaks or other types of failure occur at a node of one of the numerous natural modes of vibration of the structure. These natural modes of vibration can be determined theoretically if the structure is simple and the parts are of geometrical form, but usually the problem is too complicated for exact solution and the best that can be hoped for from theory is a rough approximation of the resonant frequencies and a still rougher approximation of the location of the nodes of the vibrating system. The present paper describes a simple method and means for experimentally determining the several natural resonant frequencies of any mechanical system and the location of the nodes of their respective standing wave systems. Its effectiveness is demonstrated by analysing three modes of vibration of a ship's propeller.

Resonance in Truncated Cones. (A. E. Bate, Phil. Mag., Vol. 26, No. 178, Nov., 1938, pp. 752-7.) (62/57 Great Britain.)

(*a*) The open-end correction appears to be independent of the frequency in the cylindrical pipe, but varies with it in conical pipes.

(*b*) When the cylindrical pipe terminates in a conical pipe of semi-apex angle of about 1-2°, the end correction disappears, the actual value of the angle at which this occurs depending on the frequency.

(*c*) For cones of large angle the correction (measured along the axis) is negative, and remains so up to about 86°; the cone angle 90° is a plane flange with a positive end correction.

(*d*) The conical pipes closed at the narrow end have natural resonant frequencies below about 10° semi-apex angle, the wave length being four times the slant height—including the appropriate correction for the unattached end.

(*e*) Conical ends above about 10° behave as conical flanges.

(*f*) The relation between frequency, slant length, and angle for cones of small angle is obscure.

Heat Transfer from Tubular Elements to Air in Cross Flow. (R. Benke, Archiv für Warmewirtschaft, Nov., 1938, pp. 287-8. Metropolitan Vickers Technical News Bulletin No. 634, p. 11.) (62/58 Germany.)

The question as to whether an in-line or a staggered arrangement of the tubes creates more favourable conditions of heat transfer has not been finally determined. The author describes tests carried out on a modern type of air heater in which the current of air is heated electrically by tubular elements (Backer tubes). He reaches the conclusion that the heat transfer is independent of the arrangement and distances apart of the tubular elements combined in the bank. Illustrated with four diagrams and one photograph.

The Pressure Available for Ground Cooling in Front of the Cowling of Air-Cooled Engines. (G. W. Stickle and U. T. Joyner, N.A.C.A. Tech. Note No. 673, November, 1938.) (62/59 U.S.A.)

A study was made of the factors affecting the pressure available for ground cooling in front of a cowling. Most of the results presented were obtained with a set-up that was about one-third full scale. A number of isolated tests on four full-scale aeroplanes were made to determine the general applicability of the model results. The full-scale tests indicated that the model results may be applied qualitatively to full-scale design and quantitatively as a first approximation of the front pressure available for ground cooling.

The available pressure in front of the cowling increased rapidly with propeller radius up to 30 or 40 per cent. of the propeller radius. The cowling should be located as close to the propeller as practicable.

Discs located in front of the nose of the cowling greatly increased the average pressure in front of the engine baffles. It is important that the plane of the disc be even with the nose of the cowling. A round-edge disc was superior to a straight flat disc. The size of the disc should be such that the area of the front opening is optimum for the total conductivity used.

Tests on full-scale aeroplanes showed that the model tests may be qualitatively applied to full-scale design and quantitatively applied as a first approximation of the available front pressure.

A Survey of Ultra-High Frequency Measurements. (D. L. Nergaard, R.C.A. Review, Vol. 3, No. 2, Oct., 1938, pp. 156-195.) (62/60 U.S.A.)

A simple magnetron signal generator is described. The more useful transmission line and skin effect formulæ are listed. In connection with transmission lines, it is pointed out that even at very high frequencies the quadrature component of the characteristic impedence cannot be neglected. Methods which have been used for the measurement of the following quantities are described:—

(1) *Wave Length.*—Wave length has been measured by reflection of waves in free space and transmission line wave meters. A method of determining the end correction of a transmission line wave meter is described.

(2) *Power.*—Thermocouples for the measurement of small powers are described. The use of incandescent lamps for the measurement of large powers is discussed.

(3) *Voltage.*—Diode voltmeters and thermocouples have been used for the measurement of voltage. The errors of these voltmeters are discussed.

(4) *Reactance.*—Reactance has been measured by tuning the unknown reactance to resonance with a transmission line of known characteristics. The method is illustrated by two examples: The determination of the resonant wave length, the inductance and capacitance of a diode, and the calibration of a variable condenser.

(5) *Resistance.*—Resistance has been measured by the substitution method, the resistance variation method, and the reactance variation method.

(6) *Current.*—The measurement of current with thermocouples is discussed.

Temperature Reduction in High-Powered Loudspeakers. (F. Massa, R.C.A. Review, Vol. 3, No. 2, Oct., 1938, pp. 196-202.) (62/61 U.S.A.)

An ideal loudspeaker designed for high-power output is ultimately limited in its rating by the maximum permissible temperature that can be safely tolerated by the voice coil structure which is generally the hottest operating portion of the speaker. The high voice coil temperature results from the insulating film of air which separates the voice coil from the magnetic structure. Data are presented showing the reduction in temperature rise which resulted when the air in the air gap of two speakers was replaced by helium and hydrogen, each gas having a higher thermal conductivity than air. The reduced voice coil temperature permits either the lowering of the voice coil dimensions with a corresponding decrease in weight of the magnetic structure, or operation of a given structure at greatly reduced temperature. A small weight high-powered speaker is particularly desirable for special applications, such as public address from aircraft. If weight is of no importance, the cooler operation due to the use of helium or hydrogen in the gap will permit an increased operating efficiency of the speaker.

Microphone Wind Screening. (W. D. Phelps, R.C.A. Review, Vol. 3, No. 2, Oct., 1938, pp. 203-12.) (62/62 U.S.A.)

Some principles of hydrodynamics applicable to the problem of screening a microphone from pressure fluctuations due to wind are considered. An expression is derived for the wind pressure on a sphere assuming the air to act as a perfect incompressible fluid in irrotational motion. The pressure is found to vary both in phase and magnitude over the surface of the sphere. The Bernoulli wind screen is described which takes advantage of the pressure and phase difference existing over the surface of a microphone to reduce the wind pressure effective at the diaphragm. The effect of resistance in the vents of the screen is shown. A comparison of the wind pressure directional characteristic of the Bernoulli screen is made with that of a relatively large ellipsoidal screen.

Performance Tests of Navy Radio Meteorograph System. (H. Diamond, W. S. Hinman, Jr., and E. G. Lapham, J. Aer. Sci., Vol. 5, No. 12, Oct., 1938, pp. 484-90.) (62/63 U.S.A.)

Improvements of the navy radio meteorograph system are described and the results are given of a series of 50 simultaneous radio meteorograph and aerograph soundings under typical service conditions. The improvements have resulted in a simplified calibrating and operating procedure which affords greater accuracy of performance while at the same time increasing the allowable manufacturing tolerances. The results of the simultaneous soundings show that the radio meteorograph is sufficiently accurate to warrant its early adoption for routine use.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State, Air Ministry (R.T.P.), Kingsway, W.C.2, and will be supplied, free of charge, as far as availability of stocks permit.

Suggestions concerning new translations will be considered in relation to general interest and facilities available.

TRANSLATION NO. AND AUTHOR.		TITLE AND JOURNAL.
		ARMAMENTS.
599	D'Adhemar, R. ...	*Theory of the Gyroscopic Motion of Projectiles. General Characteristics. A Study of Approximations.* (Ann. Soc. Scientifique, Bruxelles, Vol. 56, Nos. 1 and 2, 1936, pp. 44-68 and 76-97.)
717	——	*The Japanese Air Force at the Beginning of* 1937. (Air Fleet News, U.S.S.R., Vol. 18, No. 12, December, 1936, pp. 32-8.)
764	Eberhard, O. V. ...	*On the Maximum Error in a Series and the Dispersion of a Volley.* (Z.A.M.M., Vol. 18, No. 2, April, 1938, pp. 128-35.)
775	Meyer, R.	*High Explosive Shells.* (Z.V.D.I., Vol. 82, No. 30, 23/7/38, pp. 879-83.)
776	Server, O. B. ...	*Oerliken Cannon Ring Mount for Aircraft.* (W.T.M., Vol. 42, No. 9, Sept., 1938, pp. 411-5.)
		METEOROLOGY.
770	Findiesen, W. ...	*Meteorological Physical Conditions for Ice Formation in the Atmosphere.* (Paper read at the Annual General Meeting of the Lilienthal Gesellschaft for Luftfahrtforschung, 13/10/38.)
771	Ritz, L.	*Ice Formation.* (Paper read at the Meeting of the Lilienthal Gesellschaft for Luftfahrtforschung, Berlin, 13/10/38.)
		WIRELESS.
751	Eckart, G.	*The Theory of Diffraction in the Propagation of Ultra-Short Wireless Waves.* (H.F. Technik, Vol. 52, No. 2, August, 1938, pp. 58-62.)
763	Zinke, O.	*Voltage Measurement in High Frequency Technique including Ultra-High Frequencies.* (E.T.Z., No. 22, Vol. 9, 2/6/38, pp. 573-6.)
769	——	*A New Type of Radio Compass.* (Rev. de l'Arm de l'Air, No. 104, March, 1938, pp. 345-7.)

TRANSLATION NO. AND AUTHOR.		TITLE AND JOURNAL.
		AERODYNAMICS AND HYDRODYNAMICS.
704	Ferrari, C. ...	... *Dynamics of Compressible Fluids at Supersonic Velocities.* (Acta, Vol. 1, No. 4, 1937, pp. 29-35.)
722	Riegels, F. ...	... *Criticism of the Hele - Shaw Experiment.* (Z.A.M.M., Vol. 18, No. 2, April, 1938, pp. 95-106.)
742	Tollmein, W.	. . *The Indeterminateness of the Hydrodynamical Momentum in a Fluid Extending to Infinity.* (Z.A.M.M., Vol. 18, No. 3, June, 1938, pp. 151-4.)
		AIRCRAFT AND ACCESSORIES.
767	Kiel, G. ...	.. *A Method of Calibrating Aircraft Pitot Tubes.* (Luftwissen, Vol. 5, No. 6, June, 1938, pp. 219-23.)
768	Ritz, P. M. ...	... *Wing Flutter when Taking into Account the Vibrations in the Direction of Maximum Stiffness.* (Trans. C.A.H.I., No. 340, 1937.)
772	Vedrov, V. ...	... *Adverse Effects of Mass Balancing the Elevator on the Statical Stability of Aircraft.* (Aeron. Eng., U.S.S.R., No. 5, May, 1938, pp. 1-4.)
773	Weinig, F. ...	... *Aircraft Propellers Operating in Opposite Directions.* (Jahrbuch der deutschen Luftfahrtforschung, Vol. 1, 1937, pp. 215-23.)
774	Eick, H. ...	... *The Minimum Resistance of High Speed Aircraft.* (L.F.F., Vol. 15, No. 9, 10/9/38, pp. 445-62.)
		ENGINES AND ACCESSORIES.
761	Flucke, F. ...	... *Historical Development of the Variable Pitch Propeller.* (Luftwelt, Vol. 5, No. 5, May, 1938, pp. 163-6, and No. 6, June, 1938, pp. 195-7.)
762	Wiegand, H.	... *The Strength of Subsidiary Connecting Rods in Aero Engines.* (Luftwissen, Vol. 5, No. 8, August, 1938, pp. 289-92.)
		MISCELLANEOUS.
706	Honl, H. ... Schmid, E. ...	... ... *Theory of the Damping of a Simple Vibrating System by Coupling up its Velocity to a Free Inert Mass.* (Jahrbuch der Deutschen Luftfahrtforschung, 1937, Vol. 3, pp. 37-41.)
737	Tollmien, W.	... *The Estimation of Errors in Adams' Method for Integrating Ordinary Differential Equations.* Z.A.M.M., Vol. 18, No. 1, February, 1938, pp. 83-90.)

ABSTRACTS OF PATENT SPECIFICATIONS.

(Specially abstracted for the Journal by W. O. Manning, F.R.Ae.S.)

Abstracts of Patent Specifications received by the Society are published in the Journal. It should be noted that these abstracts are specially compiled by Mr. W. O. Manning, F.R.Ae.S., for the Journal and are only of those actually received and subsequently bound in volume form for reference in the library. These volumes extend from the earliest aeronautical patents to date, and form a unique collection of the efforts which have been made to conquer the air.

The Council accept no responsibility whatever for the accuracy of the abstracts and in any case of doubt the full patent can be consulted when necessary in the Library of the Society.

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AEROPLANES—GENERAL.

493,836. *Improvements in or relating to Aircraft.* Back, W. E., Mancroft Towers, Oulton Broad, Suffolk. Dated March 13th, 1937. No. 24,229.

This specification refers to a thick sectioned cantilever monoplane having aileron control so arranged that the ailerons can be moved differentially for banking or together for climbing or diving and a separate lever for utilising the ailerons as an air brake. The machine proposed has a wide chord in the centre while the wings taper towards the tips. The wings are swept appreciably forward so that the leading edges of the wings at the tips may be forward of the leading edge of the centre section. The machine is stated to resemble an eagle in soaring flight. The wings have a dihedral angle, have ailerons on their outer portions, control surfaces on the rear of the centre of gravity, and governing surfaces connected to the trailing edges of the ailerons so as normally to lie in equilibrium in the air stream, and which tend to move the ailerons when the air stream alters.

493,655. *Improvements in and relating to Aircraft.* N. V. Berde, Hillegomsche Maatschappij tot Exploitatie van Onroerende Zaken, Hillegom, The Netherlands. Convention date (Netherlands), June 29th, 1936.

The proposed aeroplane is claimed to have a large speed range, to be stable and to be easily controlled. The wing is composed of various sections which, when closed up, form a wing with a stable C.P. position. When the sections are spread apart they form a slotted wing. The forward section moves forward and at least one of the sections can rotate about a spanwise axis. The arrangement is such that the centre of lift is unaltered when the wing is unfolded.

493,762. *Improvements in or relating to Aircraft.* Back, W. E., Mancroft Towers, Oulton Broad, Suffolk. Dated March 13th, 1937. No. 7,387.

This specification relates to aeroplanes in which the C.P. of the outer part of each wing lies in front of the centre of gravity of the machine while the C.P.

of the inner part of each wing is in the rear of the centre of gravity. There are surfaces in rear of the centre of gravity which assist longitudinal balance. The trailing edge portions of the inner parts of the wings can constitute stabilising surfaces while the after control surfaces are situated in rear of the stabilising surfaces. The outer part of each wing has an angle of incidence which is preferably greater than that of the inner part of the wing. Ailerons are fitted to the outer section of the wing and the wings may have a dihedral angle.

494,863. *An Auxiliary Wing for Aircraft.* Blume, W., Schillerstrasse 3, Brandenburg (Havel), Germany, and Arado Flugzeugwerke Gesellschaft mit beschraenkter Haftung, Brandenburg (Havel), Germany. Dated Nov. 17th, 1937. No. 31,577.

The wing proposed has a nested extension flap or auxiliary wing carried by levers so that the flap may be swung downwards and rearwards over its whole width, and it can serve either as a lift-increasing flap or as an aileron.

AIRCRAFT—CONSTRUCTION.

493,627. *Improvements in Aircraft Structures.* Huth, F., 8, Ecksteinweg, Berlin, Johannisthal, Germany. Dated April 16th, 1937. No. 10,932.

It is proposed to construct aircraft bodies from plates of materials, either wood, metal or plastics, and the various interconnecting members of the structure are formed with slits so as to provide interlinked joints. It is proposed to use a material which can be glued and it is stated that the joints are reliable, even when the glue dries or sets with difficulty, as the construction is such that loosening of the glued portions is impossible. The proposed structure has high coherence by itself, but the strength is still further increased by the binding medium.

493,471. *Extendible and Contractile Strut or Jack for Aerial Machines.* Turner's Motor Manufacturing Co., Ltd., and Milner, H. C., of the Company's Works, Moorfield Road, Wolverhampton. Dated April 10th, 1937. No. 10,255.

The proposed jack has a group of locking elements and an auxiliary piston mounted on the main piston, arranged so that the former has a movement relative to the main piston when the elements arrive at the locking rebate and the locking is effected by a positive action. The locking plungers have inclined surfaces at their outer ends, a locking rebate in the cylinder with an inclined wall. Locking is effected positively by a movement of the auxiliary piston when the plungers arrive at the rebate. Unlocking occurs by the co-operation of the inclined surfaces on the plunger ends and the rebate.

493,761. *Improvements in Ball and Socket Joints.* Cowdrey, C. L., Derby Road, Chellaston, Derby. Dated March 12th, 1937. No. 7,357.

The joint consists of a ball carried by one member, the other portion consisting of a half socket for the ball. The rest of the socket is made up by a split ring shaped internally as a portion of the socket, and a screwed member which holds the split ring in position. A spring ring may be used if desired. In this construction the ball may be in one piece with the member to which it is attached.

491,302. *Improvements in and relating to Bracing Members for the Wings, Steering Surfaces and the like of Aircraft.* Junkers, Flugzeug-und-Motoren-werke, Aktiengesellschaft, 39, Junkers-strasse, Dessau, Anhalt, Germany. Convention date (Germany), Aug. 3th, 1938.

It is proposed to use in the spars of aeroplane wings, etc., a web plate which is curved in cross section while sections of standard form are used for the flanges. The flanges adapt themselves to the contour of the wing while the curvature of the webs is such that the webs meet the flanges at the normal angle. Hence

the depth of the spars is the maximum possible. The web plates can be of any standard form, plain or profiled, or corrugated.

491,358. *Improvements in and relating to Cabins for Aircraft.* Junkers, Flugzeug-und-Motoren-werke, Aktiengesellschaft, 39, Junkers-strasse, Dessau, Anhalt, Germany. Convention date (Germany), Dec. 28th, 1936.

The part of the fuselage enclosing the occupants is formed of transparent material in the shape of a self-supporting dome, the axis of the dome being the longitudinal axis of the body or an axis parallel thereto. The dome may be situated at one end of the fuselage or an annulus may be arranged at any point intermediate between the ends. Lattice structural members are dispensed with so that there is nothing to obstruct the sight. Designing the transparent wall as a self-supporting shell enables it to support pressure as in the case of cabins intended for high altitude flying. Supporting structural members may be used in addition.

492,289. *Improvements in or relating to Mechanics' Platforms for Aircraft.* United Aircraft Corporation, 400, South Main Street, East Hartford, Connecticut, U.S.A. Convention date (U.S.A.), March 17th, 1936.

The proposed platform is carried inside the wing and is hinged about the lower part of the fixed portion of the wing. When it is in a closed position it forms part of the wing aerofoil curve. When it is in use as a platform it is supported horizontally and part of it may be moved outward to increase the area of the platform.

494,888. *Improvements in and relating to the Positioning of Jigs or the like for Supporting a Work Piece during Construction or Assembly.* Junkers Flugzeug - und - Motorenwerk, Aktiengesellschaft, 39, Junkers - strasse, Dessau, Anhalt, Germany. Convention date (Germany), April 8th, 1937.

It is proposed to check the position of jigs by using a pattern corresponding to the assembly parts, the jigs being arranged in the erecting arrangement so as to engage with lugs in the pattern so that the adjustment can be easily obtained before the jigs are locked in position. If the pattern is not rigid it is itself first aligned by means of plans of reference which may be indicated by wires or optical base lines.

494,936. *Improvements in or relating to Fuselages for Aircraft.* Arado Flugzeugwerke Gesellschaft mit beschraenkter Haftung, Brandenburg (Havel), Germany. Convention date (Germany), Sept. 16th, 1937.

The fuselage consists of individual longitudinal plates connected with each other by riveting or welding, the plates consisting of plain plates alternating with flanged plates. The plates may be of trapezium form with flanged margins and plain plates in the form of staves.

AIRSCREWS.

493,145. *Pressed Articles, particularly Airscrew Blades, of Laminated Wood and Method of Manufacturing the Same.* Zablousky, B., Brettenham House, Lancaster Place, Strand, London, W.C.2. Dated March 31st, 1937. No. 9,219.

The proposed wooden airscrew blade is hollow and consists of two shell sections which are formed separately and joined together. Each section consists of several thin wooden laminations which are glued together, the wood fibres running mainly parallel and longitudinally. The assembly is pressed between two shaped dies so that the shell is formed to shape and increased in density, the pressure being maintained until the adhesive has hardened.

ARMAMENT.

494,399. *Aerial Bombing Devices.* Connolly, E., Springer Sturgeon Gold Mines, 67, Yonge Street, Toronto, York, Ontario, Canada. Dated March 26th, 1938. No. 9,351.

The proposal consists of a composite aircraft of which the upper member is a glider. The lower component has a vertically grooved flange extending around the front of the cockpit, the glider carries an endless collar which fits within the flange of the power plane. The separation takes place by a strap fitting the groove adapted to extend round the flange carried by the lower component and means are provided for uncoupling the divided ends of the strap. It is intended that separation shall take place near the bomb target and that, after gliding to the bombing position and directing the glider to the target, the pilot is to escape by parachute.

495,047. *An Improved Method and Means for Preventing Freezing of Machine Guns Mounted on Exposed Positions on Aircraft.* Martin, J., Higher Denham, Uxbridge, Middlesex. Dated May 6th, 1937. No. 12,949.

The guns are mounted in closed compartments in the aeroplane, which compartments are warmed by leading into them hot air from the engine compartment. It may be circulated by forced and or induced draught, and it may either be allowed to escape or be returned to the engine compartment. Inlet arrangements may be used to ensure that the hot air is suitably distributed through the compartment.

494,248 *Improvements in and connected with Adjustable Windscreens for Use in conjunction with Guns, Cameras, and Other Instruments Mounted on Aircraft.* Vickers (Aviation), Ltd., and Wallis, B. N., Weybridge Works, Brooklands Road, Weybridge, Surrey. Dated April 23rd, 1937, No. 11,643; and March 10th, 1938, No. 7,484.

The windscreen is flexible and has a gun slot so that the gun projects in such a manner that the gun carries the screen with it when the gun is trained, but otherwise the screen can move relatively to the gun towards and away from the training axis. The screen is arranged to keep to a predetermined shape as it moves round. The windscreen may be a flexible or articulated band which moves with the gun when training, but otherwise the movement of the two is independent.

CONTROL OF AIRCRAFT.

492,300. *Improvements in or connected with Air Brakes for Aircraft.* Short Bros. (Rochester and Bedford) and McVie, R., both of Seaplane Works, Rochester, Kent. Dated March 18th, 1937, No. 7,960; and Sept. 4th, 1937, No. 24,214.

The proposed air brake is mounted on the aircraft wing flap and is operated by fluid pressure, the supply of fluid being controlled electrically so that the resistance flap can be operable independently of the wing flap in whatever position the latter may have. The resistance flap, when closed, is entirely within the contour of the wing flap. Locks may be provided for locking the resistance flap in either the open or closed positions, the locks being operated electrically. The fluid pressure pumps may be operated electrically and electric indicators may be provided.

493,652. *Apparatus for Controlling the Operation of Devices Operated by Fluid Pressure such as Aircraft Flaps.* Dunlop Rubber Co., Ltd., 32, Osnaburg Street, London, N.W.1; Beharrell, G. E.; Wright, J.; and Trevaskis, H., all of the Company's Works, Fort Dunlop, Erdington, Birmingham.

The apparatus concerns the operation of a wing flap operated by a pneumatic jack. The control device proposed has a number of valves which are adapted

to be selectively operated in predetermined sequence where the flap can be raised or lowered or moved to a wind position and automatically locked in such position. The valves are arranged in two groups, each of which is operated by a separate cam. One valve or a pair of valves is operated to admit air to the jack to raise or lower the flap, while another valve controls the automatic locking.

493,198. *Improvements in Index Mechanisms for the Steering Wheels of Vehicles.* Pauli, K. M., Saltsjobaden, near Stockholm, Sweden. Convention date (Sweden), May 14th, 1937.

This is an apparatus by means of which the direction of motion of a vehicle as set by the steering wheel is indicated directly. A pinion on the steering shaft is engaged with a toothed rack which is fitted on the internal side of a rotably mounted ring. An index member is fixed on this ring, the gearing being such that it will show the direction of movement as set by the steering wheel.

493,391. *Improvements in or relating to Flaps for Aerofoils.* The Fairey Aviation Co., Ltd., North Hyde Road, Hayes, Middlesex; and Youngman, R. T., Walcot, Church Crookham, Aldershot. Dated Aug. 19th, 1937, No. 22,805; and March 16th, 1938, No. 8,153.

It is proposed to use a flap which can be lowered bodily below the level of the wing and which can be turned about an axis at or near to the centre of pressure to raise the leading edge of the flap. The leading edge can be raised or lowered until the plane of the flap is nearly normal to the wing.

493,427. *Device for Controlling the Gliding Angle in Aircraft.* Orado Flugzeugwerke Gesellschaft mit beschrankter Haftung, Brandenburg (Havel), Germany. Convention date (Germany), Aug. 14th, 1937.

The proposed device consists of a number of flaps adapted to be swung away from the wing. The flaps are coupled with one another and the flap opening in the direction opposed to the direction of flight is smaller than the flap opening in the direction of flight. The smaller flap is arranged in front of the larger one so that in the swung out position the smaller flap partially covers the other.

491,664. *Improvements in Control Means of Land Vehicles, Aircraft and Watercraft.* Sampietro, A. C., 3, Observatory Gardens, London, W.8. Dated March 10th, 1937. No. 7,104.

In a vehicle provided with an accumulator which forms part of the electrical equipment, and which is mounted so as to be capable of displacement relative to the frame of the vehicle in response to change in the state of motion of the vehicle, it is proposed that displacement of the battery in response to a change of motion of the vehicle shall be used to operate controls. The movement of the battery may be used to accentuate the change, or to oppose it.

491,505. *Improvements in or relating to Control Mechanisms for Aircraft and other Vehicles.* The India Rubber, GuttaPercha and Telegraph Works Co., Ltd., Thames House, Millbank, London, S.W.1; Webb D.; and Tarris, F. J., of the Company's Works, Silvertown, London, E.16. Dated March 2nd, 1937. No. 6,243.

This specification relates to dual control mechanisms which permit control to be effected from either one of two control positions. Means are also provided at one control whereby the other can be cut out. A cam is provided between a pair of cables which operate a control, the fulcrum of the cam can move so as to produce slack in the cables, while it can be held firmly when the cables are in use. The control of this movable fulcrum is operated from the first control position.

493,709. *Improvements in or relating to the Control of Aircraft.* Gallay, H. M., 21, Yorke Street, Glace Bay, Cape Breton Island, Nova Scotia, Canada. Dated April 10th, 1937. No. 10,244.

In combination with an aeroplane wing having normal ailerons it is proposed to use an external flap which extends right across the wing except the fuselage. The flap is behind or below and behind the trailing edge of the wing and the trailing edges of the ailerons. Means are provided to enable its incidence to be altered. The ailerons and the flap are relatively so mounted as to clear each other in operation.

491,538. *Improvements in or relating to Aircraft.* Westland Aircraft, Ltd., Yeovil, Somerset, and Widgery, W. M., of the Company's address. Dated March 6th, 1937. No. 6,714.

In the case of a balanced aircraft control member it is proposed to arrange a pair of stationary shields disposed one on each side of the forward part of the control member having their outer surfaces comforming with the shape of the associated aerofoil and terminating rearwards in the vicinity of a plane normal to the longitudinal axis of the aircraft and containing the said hinge axis. The control member has its forward part of such shape that it can be moved over the desired range in the space between the shields.

491,549. *Improvements relating to Aircraft Controls.* Phillips and Powis Aircraft, Ltd., The Aerodrome, Reading, Berkshire; and Emery, G. A. St. C., of the Company's address. Dated May 18th, 1937. No. 13,849.

The proposed control comprises means for operating an angularly movable control surface consisting of a link pivoted at one end directly to a lever arm on the surface controlling the angular movement of the surface and supported between its ends by guide means allowing combined sliding and angular swinging motion, the link carrying a cam follower co-operating with a cam formation on a member rotatably mounted on a part relative to which the control surface is angularly movable. The control surface may consist of a first control surface movable on a second control surface which later is movable about the aircraft, the rotatable member being carried by the second surface. The first control surface may be a trimming tab.

494,496. *Control Device for Aircraft.* Arado Flugzeugwerke Gesellschaft mit beschrankter Haftung, Brandenburg (Havel), Germany. Convention date (Germany), June 7th, 1937.

Between the control column and the elevator it is proposed to insert a linkage incorporating a transmission that is variable by the dynamic pressure existing, due to the motion of the aircraft, which linkage in every position of the transmitting device affords a rigid connection between the control column and the elevator. The linkage permits the use of the maximum throw of the control column possible at the lowest pressure.

494,579. *Improvements in the Means for Controlling the Movements of Ailerons, Rudders, Elevators, or other Moving Surfaces of Aircraft.* Tampier, R., 1, Rue de Bellevue, Boulogne-sur-Seine, France. Application dates, April 22nd, 1937, No. 11,522; and May 6th, 1937, No. 12,948.

This specification describes a frictional device for controlling or preventing the movements of ailerons, rudders, elevators, or other moving parts of aircraft, and consists of a ball and socket, the socket being made in two parts which can be adjusted so as to vary the friction between them and the ball. The ball and socket constitute a hinged connection between the control surface and the machine. By means of a cam acting on a spring, which forces the parts together, the friction may be controlled from the cockpit of the aeroplane.

494,961. *Locking Aircraft Control Surfaces.* Flugzeugwerke Halle G.m.b.H., 70, Boelckestrasse, Halle (Saale), Germany. Convention dates (Germany), May 2nd, 1936; Nov. 14th, 1936; and Nov. 24th, 1936.

It is proposed to lock the controls for the purpose of preventing fluttering when the machine is parked. There is a bolt for locking the surface, a manually controlled mechanism for operating the bolt, means for locking the mechanism, and an automatic control under the command of a part which must be operated when the aeroplane is started, for releasing the locking. This device may be operated by a part of the undercarriage, a cam on the accelerator by the tail skid, etc.

ENGINES.

493,651. *Mounting of Aircraft Engines.* Horrocks, W. A., 1, Devon Court, Villa Road, Nottingham. Dated June 15th, 1937. No. 16,569.

It is proposed to support an aircraft engine from four points by members which do not need crossbracing and from which the engine may be lifted without fouling the mounting. The construction proposed is tubular and a horizontal member is provided for the engine feet which is stiffened laterally by a kingpost construction. Both engine feet are connected to the upper and lower frame points by means of tubes or tie-rods, which are connected to the structure in the neighbourhood of the feet.

493,673. *Improvements in and relating to Radiators for the Engines of Aircraft or other Vehicles.* Junkers Flugzeug-und-Motorenwerke Aktiengesellschaft, 39, Junkerstrasse, Dessau, Anhalt, Germany.

The proposed radiator is of annular form arranged in an annular passage formed on the inner side of the engine cowling which approximately forms a body of revolution. It tapers towards the front. There is a surrounding shell, the arrangement being such that the air intake of the radiator is exposed to an unrestricted air flow, while the outlet consists of an annular channel which tapers towards the rear, the issuing air flowing smoothly over the engine cowling.

493,328. *Improvements in and relating to the Resilient Mounting of Motors for Vehicles and Aircraft.* Getefo Gesellschaft fur Technischen Fortschritt m.b.H., 13, Woyrschstrasse, Berlin, W.35, Germany.

The motor is resiliently mounted by rubber blocks inside a ring-like frame, so that its C.G. lies approximately in the plane of the frame. The frame is fixed to the vehicle. The frame and the framework may be divided up into groups.

491,483. *Improvements in or relating to Exhaust Systems for Aircraft Engines.* Mercier, P. E., 11, Rue Jacques, Neuilly-sur-Seine, France. Convention date (France), Dec. 24th, 1937.

It is proposed that flame shall be suppressed by cooling the gases and discharging them in the form of a sheet between two layers of air. The exhaust pipe is progressively flattened between the engine and the outlet and is bent so that the outlet is substantially parallel to the direction of flight. The exhaust gases can be discharged into the interior of the cowling and the pipe may be arranged in a compartment which isolates the exhaust pipe from the spaces traversed by the cooling air for other parts of the engine.

494,413. *Improvements in or relating to the Casings or Cowlings of Aircraft Engines.* Scott, B. D., Blewbury House, Blewbury, Berks. Dated March 19th, 1937. No. 8,191.

It is proposed to house wing engines in cowlings which project well forward of the plane and which are of an aerofoil section. The upper surface of the

cowling is faired into the wing at the trailing edge and the front of the cowling may be faired away from the propeller hub. Air inlets for cooling air may be formed in the front portion of the cowling and the exits may be above or below in the rear of the cowlings.

494,576. *An Improved Method of and Means for Mounting Air-Cooled Engines on Aircraft.* Richard, P. A., 6, Avenue Anatole France, Clichy (Seine), France. Convention date (France), March 10th, 1937.

This specification refers to aircraft having engines buried in the wing. There is a blower arranged in the wing which is in communication with the engine housing, the blower being so arranged as to increase the pressure of the cooling air or a mixture of cooling air and exhaust gas only after the air has performed its cooling function. Use may be made of the cooling air and sometimes of the exhaust gas to produce an auxiliary propulsive effect of the reaction type.

495,369. *Improvements relating to the Installation of Air Filters in Aircraft.* Vokes, C. G., 95-105, Lower Richmond Road, Putney, London, S.W.15. Dated May 7th, 1937. No. 20,795.

The filtering arrangement may be arranged within the fuselage and air is collected at a pressure depending on the speed of the aircraft so that a supercharging effect is obtained at high speeds. The filtered air may be delivered to the carburettors of the engine or may pass into the space containing the engine, all ways of access to this space being protected by filters.

495,346. *Improvements relating to the Starting of Internal Combustion Engines.* Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany. Convention date (Germany), Oct. 8th, 1936.

The arrangement comprises gearing operative only during starting interposed between the engine and the mass driven by it. The gearing is driven by the starter and is normally disengaged from the engine. Means are provided so that the energy stored in the rotating mass may be applied for engine starting. Between the engine and the rotating mass there is an automatic clutch which is gradually brought into operation and the gearing is arranged so as to give a speed reduction between the starter and the rotary mass. The automatic clutch closes when the engine overruns the rotary mass and opens when the latter overruns the engine.

PARACHUTES.

492,140. *A New and Improved Parachute and Method of Manufacturing Same.* Tinssonnier, G., 42, Rue Labouret, Colombus (Seine), France. Convention date (France), Feb. 22nd, 1937.

The proposed parachute has a surface composed of synthetic impermeable material such as cellulose acetate. A sheathing which may be composed of non-elastic threads or ribbons is fixed on the surface, the suspension cords being attached to the reinforcements.

REFUELLING.

491,953. *Improvements in the Method of and Apparatus for Refuelling Aircraft in the Air.* Sir Allan J. Cobham, K.B.E., Johnson, H. C., and Allison, P. R., all of Ford Aerodrome, Yapton, Sussex, and Flight Refuelling, Ltd., 8, Sergeants' Inn, Temple, London, E.C.4. Dated Dec. 10th, 1936, No. 33,975; April 3rd, 1937, No. 9,493; and Aug. 19th, 1937, No. 22,737.

In the refuelling of aircraft during flight it is proposed to use the combination of a ball or socket component of a hose coupling intended to connect a refuelling hose carried by one aircraft with the fuel tank of another, a device for clamping

this component in liquid-tight engagement with a mating component. The device can be released at will and releases automatically under an abnormal pull. The component may have a valve which is normally closed but which can be opened by the clamping device.

ROTORCRAFT.

493,149. *Improvements in and relating to Aircraft with Sustaining Rotors.* The Cierva Autogiro Co., Ltd., Bush House, Aldwych, London, W.C.2; and Bennett, 67, Grove Way, Esher, Surrey. Dated April 6th, 1937. No. 9,800.

This specification refers to a sustaining rotor for a gyroplane of the " jump take-off " type in which each blade is independently connected to the hub by at least two pivots, of which the flapping pivot has its axis in a plane perpendicular to the hub axis and inclined at an acute angle to the radial blade axis, and the axis of the other is oblique so that the projections of the last mentioned pivot axis on a plane normal to the blade axis makes an acute angle with that of the hub axis and on a plane normal to the hub axis makes, with the projection of the blade axis, an angle of not less than 90° on the leading side of the blade; the oblique pivot axis also lying further from the hub axis than the flapping pivot axis.

493,173. *Improved Aircraft.* Mercier, G. E. P., 13, Rue de la Vistule, Paris, Seine, France. Convention dates (France), Nov. 3rd, 1936, and Oct. 11th, 1937.

The proposed aircraft has a stabilising and controlling autorotation rotor or rotors, rotating about a vertical axis and tiltable by the pilot in any direction situated forward of the C.G. and above the fuselage, and fixed supporting planes aft of the C.G. fitted with flaps and vertical fins.

492,013. *Improvements relating to Rotors for Rotating Wing Aircraft.* Prof. Dept. Ing. H. Focke, 30, Strassburger Strasse, Bremen, Germany. Convention date (Germany), Aug. 16th, 1937.

In the case of rotors for rotary wing aircraft it is proposed that a surface for supporting the blade at rest is arranged outwardly from the hub beyond the pivot of the drag joint. The parts which contact have complementary shapes so as to guide the blade into the position of rest.

493,439. *Improvements in or relating to Aircraft.* Baynes, L. E., Hollands, Bourne End, Bucks. Dated March 4th, 1937. No. 6,499.

The proposed aeroplane has a normal wing and a pair of rotors, one on each side of the machine, which are so mounted that they can be moved into alternative positions at which vertical lift and forward horizontal movement are aided by the craft to a greater or less extent. Each rotor is engine driven. The pitch of the rotor blades is altered automatically during the adjustment of the position of the rotors.

494,427. *Improvements in and relating to Aircraft Sustaining Rotors.* The Cierva Autogiro Co., Ltd., Bush House, Aldwych, London, W.C.2, and Bennett, J. A. J., 67, Grove Way, Esher. Dated April 30th, 1937, No. 12,398; and Nov. 8th, 1937, No. 30,589.

The proposed aircraft has sustaining rotors with blades which are articulated to the hub by pivotal connections, including a pivot whose axis is inclined upwardly and outwardly with respect to the radial blade axis at an angle exceeding 45°, and with a driving member coaxial with and floating in the hub connected to a source of power having connections so that the driving force is transmitted to each rotor blade, so as to produce a sufficiently great movement about

the inclined pivot axis to hold the blade in the minimum pitch position as long as the rotor is driven.

494,739. *Improvements in and relating to Aircraft Sustaining Rotors.* The Cierva Autogiro Co., Ltd., Bush House, Aldwych, London, W.C.2, and Bennett, J. A. J., 67, Grove Way, Esher, Surrey. Dated April 30th, 1937, No. 28,664; and Nov. 8th, 1937, No. 30,588.

In a sustaining rotor for aircraft in which the blades are articulated for leading and lagging displacements, a central frictional damper having frictional parts which are connected to the blades and which are arranged to damp unsymmetrical leading and lagging motions of the blades relative to one another. These parts have a greater surface or a higher pressure than the frictional surfaces which damp the symmetrical motions.

495,176. *Improvements in Rotating Wing Aircraft with Side-by-Side Rotors.* Prof. Dipl.-Ing. H. Focke, 30, Strassburger Strasse, Bremen, Germany. Convention date (Germany), May 24th, 1938.

The aircraft described has two fuselages each carrying a rotor which possess separate driving arrangements. The fuselages are connected by a streamlined or wing-shaped body and they are located at a distance from each other of somewhat more than the rotor diameter. Each of the fuselages has a single-wheeled undercarriage, preferably retractable. The driving arrangements of the two rotors are synchronised.

495,333. *Improvements in or relating to Aircraft.* Alexander, R. M., 1, St. Luke's Road, Maidstone, and Dixon, F. S., of 113, Loose Road, Maidstone. Dated May 10th, 1937. No. 13,331.

The aircraft described has positively driven rotary wings for providing lift. There are also elongated lifting surfaces and the upper one and sometimes the lower one has a gas envelope combined with its upper surface and there are also airscrews for propulsion; these airscrews are capable of being tilted. In plan form the lifting surfaces are of ovoid shape.

UNDERCARRIAGES.

493,440. *Improvements in or relating to Hydraulic Valves.* The India Rubber Gutta Percha and Telegraph Works Co., Ltd., Thomas House, Millbank, London, S.W.1; Tarris, F. J.; and Webb, B., of the Company's Works, Silvertown, London, E.16. Dated March 4th, 1937, No. 6,500; and June 25th, 1937, No. 4,782.

A hydraulically operated brake mechanism with a hydraulic circuit which is closed against loss of hydraulic pressure, through which liquid is circulated under pressure. A valve to regulate the flow of liquid under pressure to the brake. The valve has an outer member with an internal bore, an element which slides in the bore and which is chamfered at one end. Means are provided for adjusting the valve longitudinally in the bore to vary the clearance.

494,542. *Improvements in or relating to Alighting Gear for Aircraft.* Blume, W., Schillerstrasse 3, Brandenburg (Havel), Germany, and Arado Flugzeugwerke Gesellschaft mit beschraenkter Haftung, Brandenburg (Havel), Germany. Dated Nov. 27th, 1937. No. 32,783.

This specification refers to retractable shock absorbing tail wheels. There is a strut carrying the wheel and a strut pivotally connected thereto which rotates the mounting about a horizontal axis. The tail wheel can be steered and it is provided with a cover which in the retracted position forms an externally flush extension of the rear end of the fuselage.

491,298. *Improvements in or relating to Landing Gear for Aircraft.* Mercier, P. E., 11, Rue Jacques Dulub, Neuilly-sur-Seine (Seine), France. Convention date (France), April 1st, 1937.

In the case of aircraft having two vertical fins disposed at the extremities of a horizontal tail plane it is proposed to fit tail wheels or skids in front of the tailplane and within each vertical fin. There may also be a single steerable front wheel which is streamlined by a cover which turns with the wheel.

494,557. *Improved Automatic Means for Ensuring Extension of Retractable Alighting Gear for Aircraft.* Potez, H. C. A., Meaulte, Somme, France. Convention date (France), Feb. 9th, 1938.

The wheel in this gear is carried at the end of a leg projecting from and pivoted to the body of the aircraft. It is connected at an intermediate point on its length to a fixed axle through a jointed strut comprising a device acting like a compression spring and having its ends attached to the branches of the jointed strut so that the device tends to straighten the strut against the action of the retracting gear. The object is to ensure that the chassis can be extended if the normal extending gear fails.

REVIEWS.

THEORETICAL HYDRODYNAMICS.

By L. M. Milne-Thompson, M.A., F.R.S.E. Published by Macmillan and Co., Ltd. Price 31s. 6d.

Professor Milne-Thompson, who is Professor of Mathematics in the Royal Naval College, Greenwich, has founded this book on the lectures he has given to junior members of the Royal Corps of Naval Constructors, and it is a very interesting treatise on the mathematical theory of fluid motion with application to both hydrodynamics and aerodynamics. The mathematical treatment is based almost entirely on vector methods.

The author is to be congratulated on his method of presentation. He has a clear literary style, can explain matters in a way which makes them easy to understand, and the result is that he has produced a book which is a pleasure to read, and which is much more valuable as a text book on that account.

Whether the use of vector methods instead of the traditional presentation is an advantage for teaching is a question which can be left to those who are engaged in tuition. On this matter the author's experience must carry much weight, but it is probable that the conditions at the Royal Naval College are different from those at a university, and what may be suitable for one may not be suitable for the other. It should be said that the author has included a chapter on the properties of vectors, which are essential to the understanding of the book so that those who already possess a knowledge of the elements of infinitesimal calculus should have no difficulty in following the treatment.

THE STRENGTH OF MATERIALS.

By John Case, M.A. Published by Edward Arnold and Co. Price 30/-.

This is the third edition of this well-known work and it differs from the others in including some additional matter and also because Chapter VI has been re-written, because, to quote Mr. Case, experience has led him to revise his ideas on the yield point of metals.

It is to be assumed that all those concerned with the calculations of structures know this work, and it is perhaps enough to say that in selection of matter and clarity of exposition it is everything that a text-book should be. It has not been written especially for aeronautical use—one looks in vain in the index for names such as Wagner, but many of the problems discussed are founded on aeronautical experience.

At the same time there are numerous problems in aeronautical structures which are solved by normal methods, and for all these, and most of those which can be found in general engineering, this textbook is excellent.

ELEMENTARY MATRICES.

By R. A. Frazer, B.A., D.Sc., F.R.Ae.S., W. J. Duncan, D.Sc., F.R.Ae.S., and A. R. Collar, B.A., B.Sc. Published at the University Press, Cambridge. Price 30/-.

This book is written primarily for students of applied mathematics and is intended generally as an introduction to the study of matrices. It is claimed by the authors, probably with truth, that it is the first treatise on this subject which refers specially to its applications to differential equations and classical mechanics.

The first three chapters introduce the general theory, while the fourth chapter discusses various numerical processes, such as the reciprocation of matrices, solution of algebraic equations, etc. Chapters V and VI deal with linear differential equations with constant coefficients, while Chapter VII deals with the solution of systems of linear differential equations with variable coefficients.

The remaining chapters are concerned with mechanics. They deal with the kinematics and dynamics of systems, motions governed by differential equations, iterative methods of numerical solution and simple dynamic systems involving solid friction. Among the examples considered there are several of much interest drawn from aeronautics. One in particular, a discussion of the critical speed for flutter of an aeroplane wing, is an excellent example of the convenience of matrices in computation.

To those for whom it is intended, and for others engaged in computations for which this method of calculation is applicable, this book can be thoroughly recommended.

DIESEL ENGINES.

By B. J. von Borgart. Published by Chapman and Hall. Price 21/-.

This is an American book dealing with all types of Diesel engines. The general treatment is comprehensive and the reader is told something about almost any aspect of Diesel design and operation. There are chapters which discuss such matters as thermodynamics, fuels, atomisation, fuel pumps, nozzles, combustion chamber designs, superchargers, etc.

The book necessarily emphasises American practice and for this reason it may be of special interest to those in this country who are working on Diesel developments. European practice is referred to, but the descriptive matter concerned with the developments on this side of the Atlantic is often weak. The Beardmore fuel pump is illustrated by a diagram, but the description occupies only some half dozen lines. Readers who may be interested in the governor and solinoid gear of this ingenious pump are left to work matters out for themselves on the diagram.

There is a chapter on the aviation Diesel which illustrates and gives a few particular details about the better known engines of this class. Among them is a diagram which purports to show the arrangement of a new Junkers barrel

type engine. This diagram would be better omitted as it is not sufficiently intelligible.

Generally the book may be useful as a record of modern practice in Diesels for it is packed with illustrations and diagrams, and it may serve also as a general introduction to the subject, but it is impossible to expect a subject of this sort to be adequately dealt with in some 320 pages. If some of the matter had been left out, and the space saved devoted to a better description of the remainder, this would have been a much more useful book.

THE FLIGHT OF BIRDS.

C. Horton-Smith. H. F. and G. Wetherby, Ltd. 1938 7/6 net.

Information about the all-important subject, to the aircraft engineer, of bird flight, is steadily increasing. That aircraft of the future will flap their wings is unlikely. That the aircraft engineer may yet learn much about airflow from a study of bird flight is more than likely, despite his, at present, rather aloof attitude. There is no doubt whatever that the flow of air over moving wings is yet not like anything understood; when it is, the reviewer does not doubt that the principles which will have been discovered will be made use of, in some form or another, to improve very considerably the already high aerodynamic efficiency of the aeroplane wing. It may even be that aircraft designers will come to believe that safety in flight is even more important than speed, a belief that is not too widely held at the present time.

Mr. C. Horton-Smith has written an extremely readable and interesting book with clear illustration which add considerably to the value of the text. Chapter III, on Wings in General, discusses the various types of birds' wings and how admirably suited they are for the particular environment of the bird and the work, so to speak, it has to do. Chapter V deals with Gliding and Soaring Flight and Chapter VI with Flapping Flight. In this latter chapter there is a very interesting summary of the ratio of the weights of the pectoral muscles to the total weight of the bird. In birds which normally fly by flapping the percentage is very high, as much as 28.9 per cent. for the snipe, for example, while gliding birds drop as low as 9.4 per cent. (the greater black-backed gull).

In the chapter on the Velocity of Flight the author states rightly that many records of bird speeds are in existence, " and it is deplorable that so few of them can be regarded as even approximately accurate." The author has not been led away by the exaggerated speeds which have been given, and the figures he gives are reasonable.

Mr. C. Horton-Smith has taken considerable trouble not only to study the literature on the subject, but he has been able to sift the valuable scraps of information from the mass of ill-arranged and often inaccurate observations which have been carried out on bird flight. He brings to his subject a trained mind and an enthusiasm which has resulted in a book which will well repay reading by all those interested in flight in any form.

CORRESPONDENCE.

[NOTE.—The following letter, received by the President, is published to correct mistakes made in the review of Jahrbuch 1937/38 der Deutschen Akademie der Luftfahrtforschung, published in the JOURNAL for October, 1938. Every care is taken in reviewing books received and the Editor is glad to have the opportunity of publishing the letter from Ministerial Director Herr A. Baeumker, Chancellor of the Deutschen Akademie de Luftfahrtforschung, to remove any misunderstanding. It should be noted that the Council are not responsible for any opinions expressed in any papers or reviews in the JOURNAL, the responsibility for which ultimately is the Editor's unless otherwise stated.]

To the Editor of the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

DEAR MR. FEDDEN,—The book review in the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY, No. 334, page 919, of October, 1938, contains statements which are not quite in accordance with facts.

The election of members of the Deutsche Akademie der Luftfahrtforschung is not carried out by the Government and will not be in the future. The methods of election in the main conform to those applying to the constitution of all academies.

On the founding of the academy the election was naturally spread over a comparatively wide circle, very much wider than is the case with an already existing academy which only has to replace members. Certainly one or other important personality is not yet suitably placed, or even perhaps not yet admitted to the academy. Provision was made from the first to revise the membership of the academy from time to time, to adjust deficiencies and especially to obtain outstanding younger men of talent. The Government, however, does not take any part either direct or indirect in these elections.

The lines upon which the academy is run and the inner organisation of individual groups are as yet by no means definitely established. No part of the Yearbook of the academy contains such a statement.

The objects of the Akademie der Luftfahrtforschung differ from those of the Lilienthal Gesellschaft inasmuch that in the academy the general scientific principles of flight are dealt with in a freer form (after the style of the old academies). Related subjects in particular and problems in natural science of all kinds receive special consideration.

On the other hand, the Lilienthal Society deals with direct technical problems of the day. The Lilienthal Society has to make clear just what aviation requires for practical utilisation now and in the near future. The work of the Deutsche Akademie is, as stated, based on fundamentals and accordingly is not bound down in its work to any time limit nor is its scope restricted.

That the members of the academy have to undertake a minimum fixed task—only one scientific lecture in a period of five years as a duty—is a condition which has to be fulfilled in most of the German universities. This ruling as regards the mode of work is therefore in no way new or dictatorial.

It would be totally misleading to assume that any official body, such as the German Air Ministry, imposes duties of any kind on this academy. The scope of the work of the academy is decided solely in accordance with the wishes of the members themselves. The German Air Ministry and other officials can only request the academy for expert opinion.

Whoever carefully reads the statutes of the academy will find that the real connection of the academy to the aeronautical directorate of the Reich is actually

only through the president, who according to para. 4, line 1, is the German Air Minister himself. The " supervision " provided for in para. 10 of the Statutes in no way goes beyond the principle which has been laid down for all German scientific academies for a long time. In the first place it refers to the control of the sums allocated from the Government grants in the sense of a properly ordered financial trusteeship. No departmental influence is hereby included.

The conclusions drawn in the last sentence of the review in the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY are also inaccurate. A number of names are mentioned. Some of these personalities were in any case envisaged for nomination as members at a suitable date. Others of those mentioned have been out of Germany for a long while. One of those named is no longer alive. This professor was at one time definitely nominated for election as a member, but unfortunately he died before the formation of the academy. This was a man who was to have been nominated as a special professor for aeronautical research purposes, by the German Air Ministry, but unfortunately he did not survive to receive the appointment.

It may be stated categorically that the Deutsche Akademie der Luftfahrtforschung cannot be regarded in any respect as " a sort of Government Advisory Body."—Yours, etc.,

(Signed) BAEUMKER.

To the Editor of the JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

SIR,—With regard to Mr. W. E. Gray's letter (your JOURNAL, 1938, p. 917), I am sorry to say that the opinion expressed by him, deduced from an otherwise correct observation, appears to be in complete disagreement with the opinions of pilots who have tried " Dart Kitten " aeroplanes.

That a wing shows a tendency to drop during attempts of stalled flights is largely due to small inaccuracies during assembly.

But one must not confuse this phenomenon with the aerodynamical fact of a *stall beginning at the wing tip* which will result in a premature loss of the lateral control and finish in a spin (the " all-too common incipient spin manner," Mr. Gray states).

Obviously, small inaccuracies in assembly (either by the manufacturer or by subsequent treatment of the aeroplane) which affect the aerodynamical qualities of cambered wing tips, such as to be found on the " Dart Kitten," will cause the dropping of a wing during a partial stall. This being due to the difference of the aerodynamic forces produced on the wing tips which are acting—Mr. Gray will agree—on a lever equal to approximately half the span of the machine.

Mr. Gray might have discovered that by proper application of the ailerons provided for this purpose it can be more or less counteracted.

I cannot but express admiration for the frank statement that to fly a " Dart Kitten " in a stalled condition is a " tricky and uncertain business." Stalling is a bad business anyway, it has killed many pilots and it should be excluded from flying performances. But it must be said that the special reference to the " Dart Kitten " seems to be contrary to the general opinion of pilots. Mr. G. M. Alington, for instance, has demonstrated in many prolonged stalled glides down to few feet above the ground, that there is nothing " tricky and uncertain " with the stall of the " Kitten."

The " Dart Kitten " can, of course, be forced into a spin by appropriate application of the very powerful rudder.

I have to apologise for the fact that Mr. W. E. Gray seems to have inferred from my reference to Mr. Relf's paper that my design is " fool-proof at the stall." I never intended to indicate that.—Yours faithfully,

A. R. WEYL.

The 636th Lecture read before the Royal Aeronautical Society since its foundation on January 12th, 1866.

PROCEEDINGS.

A Meeting of the Society was held in the Lecture Theatre of the Institution of Mechanical Engineers on Thursday, November 3, 1938, when a paper on "Meteorological Problems of the North Atlantic" was presented by Mr. Entwistle, B.Sc. (Head of Overseas Division, Meteorological Office, Air Ministry).

In the chair Mr. Griffith Brewer, Vice-President.

THE CHAIRMAN: The paper dealt with one of the most elusive subjects that had ever troubled mankind through the ages. Mr. Entwistle was well qualified to deal with it because he had been studying it for more than 20 years.

It was in 1915 that Mr. Entwistle had established his first connection with aviation, when he had lectured at Farnborough to the officers of the Royal Flying Corps. After that he served in France and later with the British army on the Rhine. From 1924 until 1934 he was superintendent of the Aviation Division of the Meteorological Office and was responsible for the organisation and supply of meteorological information for the Royal Air Force and for civil aviation. Nowadays he was responsible for the Overseas Meteorological Organisation in connection with the Empire air routes, the trans-Atlantic machines and, indeed, all the Overseas air routes.

THE METEOROLOGICAL PROBLEM OF THE NORTH ATLANTIC.

By F. ENTWISTLE, B.Sc.

(Head of Overseas Division, Meteorological Office, Air Ministry).

The development in recent years of trans-oceanic flying has raised new problems, both in regard to the design of aircraft of increased range and performance and the operational and technical questions involved, and also from the point of view of the ancillary services—radio and meteorology—on which the successful operation of an air route must, ultimately, depend.

The importance of an organised meteorological service as an adjunct to the safe, regular and economical operation of an air route has been recognised from the earliest days of civil aviation. Meteorology, however, must play an even greater part in the operation of long trans-oceanic routes than in the case of the shorter routes such as those which form a network over Europe. Apart from the longer flying times, which involve an increased risk of drift if the effect of wind is not taken fully into account, there are no intermediate airports available for emergency landings in the event of bad weather or of unexpected head winds. The navigational aids which have reached such a high degree of efficiency on overland routes do not operate with the same degree of reliability over long stretches of ocean, especially in the case of the North Atlantic where drift observations from the aircraft are difficult at night, particularly in bad weather, and astronomical navigation is frequently impossible owing to dense cloud. It is true that the development of short wave directional radio now makes it possible for bearings to be obtained from one or other of the terminal bases throughout a flight on the direct North Atlantic route. Assistance can also be obtained by taking bearings on ships. But while the medium wave direction finding system provided at the terminals operates accurately up to a distance of about 400 miles the results at greater distances with short wave direction finding cannot be

regarded as constant, although it is understood that a series of bearings gives reliable information. In any case it is clear that the utility of short wave direction finding must have certain limitations at long ranges especially when it is considered that an error of $2\frac{1}{2}^{c}$ in a bearing will result in a position error at a distance of 1,000 miles of 50 miles. It is evident, therefore, that accurate forecasts of wind and information about the variation of wind with height are of great importance in assisting navigation over the ocean. Looking at the matter from a wider angle the trans-ocean pilot is not limited by the restricted air corridors of the continental routes but is at liberty to utilise the information about the general wind distribution to choose his route in such a way that he secures the maximum help from the wind, and also knows to what extent he can circumnavigate bad weather areas without sacrificing valuable time. It is no exaggeration to state that the provision of a specialised meteorological service for trans-Atlantic flying must be identified with the radio service as an essential part of the ground organisation.

While the application of meteorology to air navigation over the oceans raises new problems, it must be regarded as a gradual development of the service which has been built up during the last fifteen or twenty years rather than as a completely new system of meteorological application. In the early days of civil aviation the first meteorological requirement was considered to be the provision of a close network of air route reporting stations which would transmit weather reports at frequent, regular intervals. Although short period forecasts were also provided and utilised, the pilot would not, normally, leave the ground until the weather reports from stations along the entire route indicated reasonably good conditions with adequate cloud base and good visibility. The introduction of multi-engined aircraft and the development of cloud and instrument flying, which resulted in the aircraft flying on direct courses between the European terminals instead of following the longer route involving the shortest sea crossing, led to an important change in the application of meteorological information. Weather reports from intermediate stations along the route became of secondary importance and the first requirement was an accurate forecast of the landing conditions which would obtain at the terminal when the aircraft arrived there. This development in civil aviation brought with it a new problem—that of ice accretion when the aircraft flew in clouds at low temperatures at or below the freezing point of water. The forecasts now issued for flying contain information regarding the levels at which dangerous ice accretion is likely to be experienced. The development of long-distance air routes such as those which now operate from England to Australia and South Africa has emphasised still more the value of accurate meteorological forecasts, particularly of wind conditions, since relatively long stages are flown on these routes.

It is evident, thus, that the meteorological service required for trans-Atlantic flying may be regarded as a further stage in the progressive development which has taken place during the last fifteen or twenty years. On the more purely meteorological side, while the advent of trans-Atlantic flying has led to a more intensive study of ocean weather conditions, the latter do not present an entirely new problem. The importance of a network of ships' observations has long been recognised since, with the prevailing west-to-east movement of weather systems it is necessary, in order to provide accurate weather forecasts for the countries of Western Europe, to identify these systems while they are still over the Atlantic and to follow their movements and developments.

Choice of Route: Meteorological Considerations.

The selection of a route or routes and the establishment and equipment of air bases at the terminals are essential preliminaries to the inauguration of a regular trans-Atlantic air service. There are three alternative routes across the North Atlantic:—

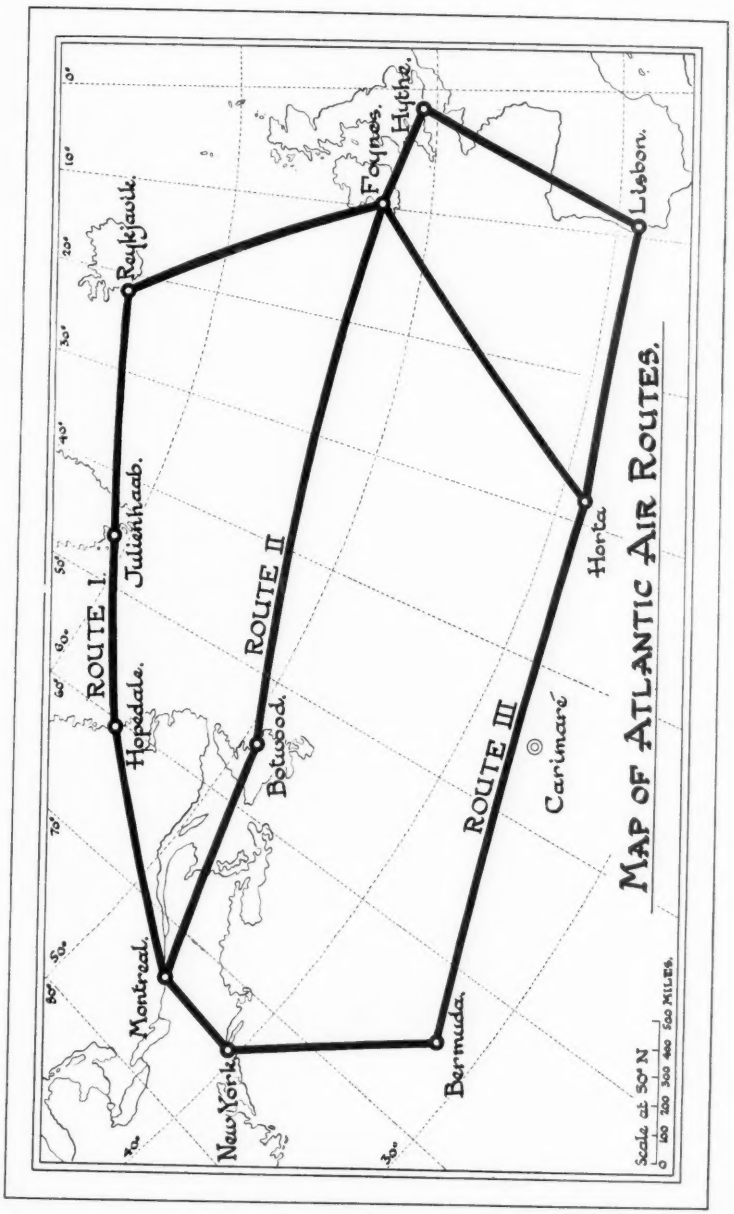

MAP OF ATLANTIC AIR ROUTES.
ROUTE I.
ROUTE II
ROUTE III
Montreal.
Hopedale.
Julianhaab.
Reykjavik.
Foynes.
Hythe.
Lisbon.
Botwood.
Horta
Carimaré
Bermuda.
New York.
Scale at 50° N
0 100 200 300 400 500 MILES.

FIG. 1.

(*a*) The Northern Route via Iceland, Greenland and Labrador.
(*b*) The Direct Route via Ireland and Newfoundland.
(*c*) The Southern Route via the Azores and Bermuda.

The three routes are shown on the map in Fig. 1. Routes (*b*) and (*c*) involve in each case a long ocean crossing of about 2,000 miles, while in the case of route (*a*) the longest stage which would be flown without landing is of the order of 900 miles.

The choice of a particular route must obviously be governed by several considerations, but from a technical point of view the most important factor is, undoubtedly, that of the prevailing meteorological conditions at different seasons of the year, both along the route and at possible air bases or refuelling stops, in so far as they would affect the regular operation of an air service. Of these conditions, the prevailing westerly winds over the North Atlantic, which increase in strength from south to north, attaining their maximum speed in winter, stand out as a predominating influence on the operation of aircraft in an east to west direction. One of the first pieces of work carried out in the Meteorological Office in the programme of Atlantic investigations which was commenced early in 1936 was the determination of the average maximum head component at a height of 2,000 feet above sea level along the direct east-west track from Ireland to Newfoundland. The results of the investigation, which was based on data extending over ten years, indicated that the maximum average west wind component was 60 m.p.h. but that this average speed only occurred once in the ten years. They suggested that if, in drawing up specifications for aircraft for the Atlantic service, the range was based on a head wind of 40 m.p.h., there would be very few occasions in the course of the year on which it would be impossible to operate the east-west service with normal load. A further point of interest in the investigation was that the length of the route affected by adverse winds of 60 m.p.h. or over varied from 100 to 900 miles but that the average extent was from 200 to 400 miles.

A more comprehensive investigation was afterwards carried out in order to provide information in greater detail regarding the times of passage between Ireland and New York in an east to west direction, and also, to effect a comparison between the times taken on the three routes.

Times of passage were computed for each day for which the necessary data were available, from daily weather charts covering a period of five years, from June, 1927, to May, 1931, and from June, 1935, to May, 1936. Measurements were made from the charts of the geostrophic winds which agree closely with the wind at a height of 2,000 feet above the surface of the sea. It was assumed that the aircraft left Foynes at 07.00 G.M.T. on each morning of the period under investigation; the ground speeds of the aircraft over the different routes were then computed, the winds being determined from the appropriate charts and the routes sub-divided as necessary.

The following data were determined for each route and for each of three airspeeds, 150, 175 and 200 m.p.h.:—

(i) The longest time for each month.
(ii) The average time for each month.
(iii) The shortest time for each month.
(iv) The annual mean time.
(v) The percentage frequencies of departures from the annual mean time.

Similar data were computed for the long ocean sections Foynes-Botwood on route II and Azores-Bermuda on route III. The results are shown for the case of an air speed of 150 m.p.h. in Tables I-IV and also graphically in Fig. 2. A summary of the times of passage, corresponding ground speeds and equivalent head winds is given in table V.

The tables provide a large amount of material for study, but it will only be possible here to note a few of the outstanding features. In general, the longest

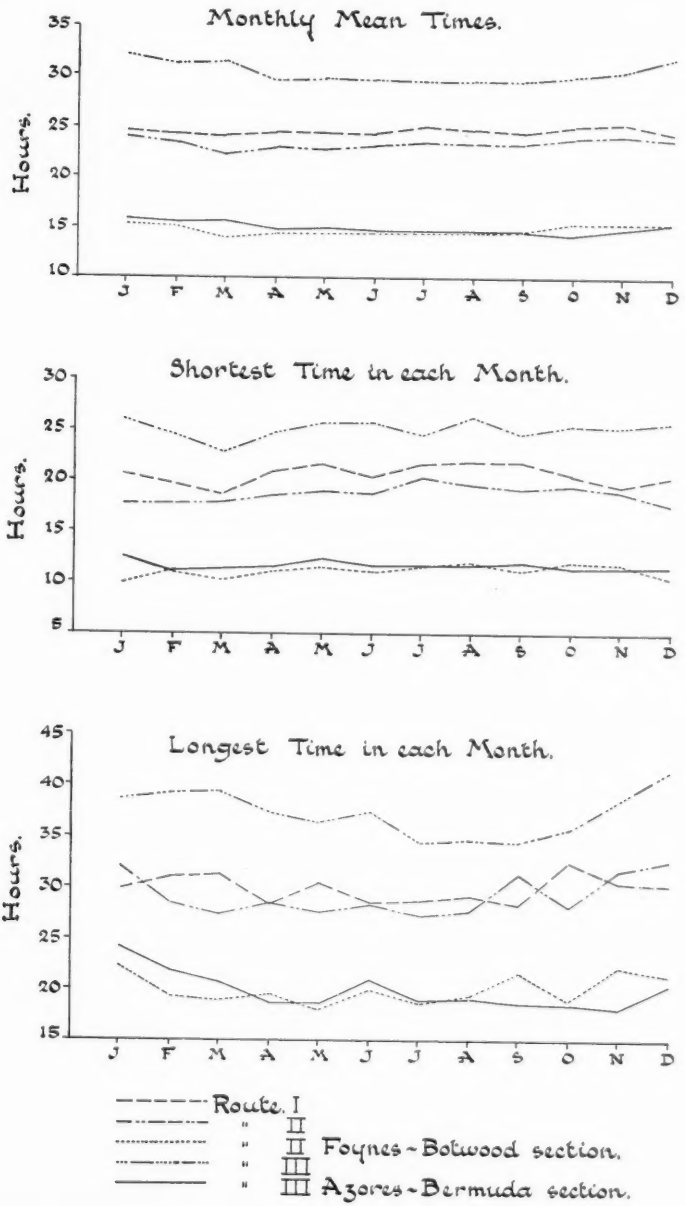


FIG. 2.

Times of passage Foynes-New York (air speed 150 m.p.h.).

TABLE I.

COMPUTED TIMES OF PASSAGE OF AIRCRAFT FROM EAST TO WEST ACROSS THE NORTH ATLANTIC. (AIR SPEED 150 M.P.H.)
MONTHLY AND ANNUAL MEAN TIMES (HOURS).

Route.	Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean Times.
I	1927-1928	25.3	24.5	23.2	24.0	24.8	24 0	25.0	24.1	24.1	23.9	*25.4*	**22.9**	24.3
	1928-1929	24.0	**23.3**	24.0	24.1	23.5	24.6	24.9	24.3	24.7	23.7	24.6	*25.3*	24 3
	1929-1930	24.8	25.0	25.5	24.9	24.3	**23.9**	25.2	25.0	25.1	*26.4*	24.7	24.7	25.0
	1930-1931	25.5	25.6	**23.1**	25.1	24.3	24.8	25.2	25.0	24.5	25.0	*26.0*	25.4	25.0
	1935-1936	23.9	24.0	25.2	24.7	25.1	24.1	25.6	25.5	23.9	*26.6*	25.8	**23.7**	24.8
	Mean Times	24.7	24.5	24.2	24.6	24.4	24.3	25.2	24.8	24.5	25.1	25.3	24.5	24.7
II	1927-1928	*25.8*	24.7	22.4	23.1	**21.5**	23.8	22.3	22.5	23.1	23.0	23.7	22.1	23.1
	1928-1929	23.2	22.9	22.9	**22.1**	23.7	22.2	23.3	23 4	23.5	*24.3*	23.8	23.5	23.2
	1929-1930	*25.1*	23.5	22.7	22.8	22.8	**22.4**	23.6	23.8	23.9	24.5	23.9	*25.1*	23.7
	1930-1931	24.5	23.9	**20.4**	23.7	22.8	24.4	23.1	23.7	22.3	23.4	24.1	*25.6*	23.5
	1935-1936	**21.9**	22.3	22.9	23.4	23.4	23.9	*24.9*	24.0	23.7	*24.9*	*24.9*	22.7	23.6
	Mean Times	24.1	23.5	22.3	23.0	22.8	23.2	23.4	23.5	23.3	24.0	24.1	23.8	23.4
II Section Foynes to Botwood	1927-1928	*16.8*	16.3	14.0	14.1	**13.2**	15.0	13.9	14.2	14.7	14.3	15.1	13.7	14.6
	1928-1929	14.3	14.6	14.4	**13.7**	15.2	**13.7**	14.6	14.5	14.7	*15.4*	*15.4*	15.1	14.6
	1929-1930	16.2	14.9	**13.9**	14.2	14.5	14.0	14.7	15.0	15.0	16.0	15.2	*16.3*	15.0
	1930-1931	15.9	15.5	**12.6**	15.0	14.3	15.4	14.4	15.0	13.7	15.1	15.3	*16.8*	14.9
	1935-1936	**13.8**	14.0	14.2	14.8	14 8	15.3	16.0	15.2	15.2	16.0	*16.5*	14.9	15 1
	Mean Times	15.4	15.1	13.8	14.4	14.4	14.7	14.7	14.8	14.7	15.4	15.5	15.4	14.8
III	1927-1928	*32.4*	32.2	31.3	30.5	29.8	29.7	29.8	**29.0**	29.1	30.5	29.8	31.4	30.5
	1928-1929	31.6	*32.3*	31.2	30.2	29.7	30.3	30.0	29.8	**29.1**	31.2	*32.3*	30.4	30.7
	1929-1930	32.2	30.0	*32.7*	**28.9**	31.9	30 2	30.2	29.5	29.0	29.4	31 3	32.6	30.7
	1930-1931	31.4	30.5	*32.2*	**29.0**	30.1	29 1	29.9	30.5	30.8	30.1	30.0	32.0	30.5
	1935-1936	32.5	31.1	29.1	29.2	**28.0**	30.2	28.7	29.7	30.6	28.4	29.0	*32.9*	29 9
	Mean Times	32.0	31.2	31.3	29.6	29.9	29.9	29.7	29.7	29.7	29.9	30.5	31.9	30.5
III Section Azores to Bermuda	1927-1928	*16.0*	15.9	15.5	15.3	15.0	15.1	14.9	**14.3**	14.5	15.0	14.4	15.6	15.1
	1928-1929	15.7	*15.9*	15.6	15.1	14.8	15.0	15.0	14.6	**14.5**	15.4	*15.9*	15.1	15.2
	1929-1930	15.6	14.8	*16.4*	14.4	15.9	15.1	15.0	15.0	**14.2**	14.4	15.6	15.6	15.2
	1930-1931	15.6	14.8	*16.3*	**14.3**	15.3	**14.3**	14.9	14.9	15.3	14.6	14.5	15.6	15.0
	1935-1936	*16.3*	15.7	14.4	14.8	14.1	14.6	14.4	15.0	14.8	**13.3**	14.2	*16.3*	14.8
	Mean Times	15.8	15.4	15.6	14.8	15.0	14.8	14.8	14.8	14.7	14 5	14.9	15.6	15.1

Black figures denote Minimum Monthly Mean Time. Italic figures denote Maximum Monthly Mean Time.

TABLE II.

Black figures denote Minimum Monthly Mean Time

Italic figures denote Maximum Monthly Mean Time

TABLE II.

COMPUTED TIMES OF PASSAGE OF AIRCRAFT FROM EAST TO WEST ACROSS THE NORTH ATLANTIC. (AIR SPEED 150 M.P.H.)
LONGEST TIME IN EACH MONTH (HOURS).

Route.	Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Longest Time in each year. Month.	Time.
I	1927-1928	29.6	27.5	25.7	27.8	28.7	27.1	26.8	26.9	26.3	27.1	29.6	26.2	Jan. / Nov.	29.6
	1928-1929	28.6	28 1	28.5	27.7	26.5	26.4	26.7	26.7	27.1	27.9	28.7	30.2	Dec.	30.2
	1929-1930	28.1	28.9	31.2	27.0	27.6	26.6	27.7	27 6	28.5	31.4	29.4	29.0	Oct.	31.4
	1930-1931	28.9	30.9	26.1	27.7	28.1	28.3	27.5	29.3	27.5	29.1	30.7	29.6	Feb.	30.9
	1935-1936	28 5	27.2	30.0	28.4	30.3	26.6	28.7	28.7	27.0	32 5	29 4	28.7	Oct.	32.5
	Longest time over 5 years	29.6	30.9	31.2	28.4	30.3	28.3	28.7	29.3	28.5	32.5	30.7	30.2		
II	1927-1928	31.6	27.7	25.4	28.3	24.6	27.2	24.1	25.6	24.8	26 9	26.7	30.7	Jan.	31.6
	1928-1929	27.9	26.2	26.4	28.3	26.5	25.5	25.5	27.7	26.9	27.4	30.1	26.0	Nov.	30.1
	1929-1930	32.0	28.2	27.4	27.5	26 8	26.6	26.5	26.7	27.5	27.5	26.0	32.6	Dec.	32.6
	1930-1931	30.7	28.5	24.2	28.4	25.0	27.3	25.1	27.8	25.5	28.1	29.0	31.2	Dec.	31.2
	1935-1936	29.0	24.8	26.0	26.3	27.6	28.1	27.1	27.6	31.2	26.9	31.4	27.7	Nov.	31.4
	Longest time over 5 years	32.0	28.5	27.4	28.4	27.6	28.1	27.1	27 8	31.2	28.1	31 4	32.6		
II Section Foynes to Botwood	1927-1928	21.1	19.4	15.8	18.1	16.2	17.3	15.1	16.9	16.9	17.0	18.0	21.1	Jan / Dec.	21.1
	1928-1929	18.3	17.7	17.5	19.4	17.9	16.6	16.0	16.9	17.3	18.2	22.1	16.8	Nov.	22.1
	1929-1930	22.2	18.5	18.9	17.9	17.8	17.0	17.0	18.1	17.6	18.8	17.2	20.0	Jan.	22.2
	1930-1931	21 2	19.5	15.2	18.1	16.6	17.1	16.6	17.8	16.0	18.2	20.0	21.5	Dec.	21.5
	1935-1936	19.0	16.5	17.1	18.2	16.9	20.0	18.6	19.5	21.8	18.2	21.4	19.0	Sept.	21.8
	Longest time over 5 years	22.2	19.5	18.9	19.4	17.9	20.0	18.6	19.5	21 8	18 8	22.1	21.5		
III	1927-1928	36.6	35.6	34.4	34 5	33.0	34.4	33.0	32.5	32.5	35.9	34.9	36 7	Dec.	36.7
	1928-1929	38.1	38.9	37.4	33.1	35.0	32.8	34.2	33.0	33.7	35.1	38.6	34.6	Feb.	38.9
	1929-1930	37.2	36.1	39.5	37.4	33.3	33.4	33.2	33.1	31.6	34.6	35.7	38.7	Mar.	39 5
	1930-1931	36 5	38.3	38.2	34 5	33.8	31.0	32.7	33.5	33.9	34.2	34 9	38 3	Feb. / Dec.	38.3
	1935-1936	38.6	39.2	35.6	34.1	31 0	37.4	32.3	34.9	34.6	32.3	32 3	41.3	Dec.	41.3
	Longest time over 5 years	38.6	39.2	39.5	37.4	36.3	37.4	34.2	34.9	34 6	35.9	38 6	41.3		
III Section Azores to Bermuda	1927-1928	17.5	17 9	17.9	18.7	17.1	21.2	16.9	16.5	16.5	17 9	16.2	18.4	June	21.2
	1928-1929	19.1	18.7	18.7	17.1	18.7	16.5	18.7	17.3	15.8	17.1	18.3	17 9	Jan.	19.1
	1929-1930	18.7	21.8	20.6	17.9	18.7	17.9	17.1	17.6	15 8	18.7	18.0	18.7	Feb.	21.8
	1930-1931	19.6	21.7	20.6	17.1	17.9	15.3	16.5	18.7	17.2	17.9	17.2	18 6	Feb.	21.7
	1935-1936	24.2	20.6	18.7	18.7	15.8	18.9	17.2	19.4	18.7	14 7	17.1	20.5	Jan.	24.2
	Longest time over 5 years	24.2	21.8	20.6	18.7	18.7	21.2	18.7	19.4	18.7	18.7	18.3	20.5		

TABLE III.

COMPUTED TIMES OF PASSAGE OF AIRCRAFT FROM EAST TO WEST ACROSS THE NORTH ATLANTIC. (AIR SPEED 150 M.P.H.)
SHORTEST TIME IN EACH MONTH (HOURS).

Route.	Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Shortest Time in each year. Month.	Time.
I	1927-1928	21.9	23.0	20.5	21.4	22 0	20.2	23.5	22.9	22.2	21.2	22.4	21.1	June	20.2
	1928-1929	20.4	19.7	18.6	21.9	21.5	23.0	22.7	22.1	22.3	20.3	20 2	20.6	Mar.	18.6
	1929-1930	21.3	22.5	21.5	21 0	22.2	20.3	23.0	22.0	22.3	22.2	19.6	20.8	Nov.	19.6
	1930-1931	22.8	20.6	19.9	21.5	21.7	21.1	21.7	22.4	21.9	21.1	21.2	22.1	Mar.	19.9
	1935-1936	21.2	20.6	20.2	20.8	22 0	22.0	22.8	23.2	22.0	23.1	23.1	20.3	Mar.	20.2
	Shortest time over 5 years	20.4	19.7	18.6	20.8	21.5	20.2	21.7	22.0	21.9	20.3	19 6	20.3		
II	1927-1928	22.9	22.0	19.8	19 5	19.1	20.8	20.5	19.7	20.9	19.5	20.4	17.7	Dec.	17.7
	1928-1929	17.6	20.0	18.6	18.5	19.2	18.9	21.2	21.2	20.0	21.1	21.0	20.4	Jan.	17.6
	1929-1930	19.7	17.9	18.2	18.6	19 8	20.1	21.5	21.0	20.5	21.4	21.2	21.5	Feb.	17.9
	1930-1931	20.4	18.3	17.9	20.9	20.1	22.1	20.6	20.9	19.9	20.0	19.0	20.0	Mar.	17.9
	1935-1936	18.2	19.4	19.3	19 4	19.5	20.3	22.0	21.4	19.2	21.6	20.5	17.6	Dec.	17.6
	Shortest time over 5 years	17.6	17.9	17.9	18 5	19.1	18.9	20.5	19 7	19.2	19 5	19.0	17.6		
II Section Foynes to Botwood	1927-1928	14.4	13.0	11.8	11.0	11 5	11.8	11.8	12.2	12.3	12.0	12.5	10.4	Dec.	10.4
	1928-1929	10.0	11 6	11.7	11.2	11.5	11.1	12.2	12.4	11.9	11.9	12.8	13.1	Jan.	10.0
	1929-1930	12.9	11.4	10.7	11 5	12 0	11.8	13.3	12.9	12.5	13.4	12.9	14.5	Mar.	10.7
	1930-1931	12.6	11.2	10.3	12.4	11 8	13.5	12.5	12 6	11.2	12.0	11.6	12.3	Mar.	10.3
	1935-1936	10.4	12.1	11.2	11.9	12 1	12.1	14.1	13.1	11.1	13.9	13.5	11.7	Jan.	10.4
	Shortest time over 5 years	10.0	11.2	10 3	11.0	11.5	11.1	11.8	12.2	11.1	11.9	11 6	10.4		
III	1927-1928	28.6	25.3	27.0	27 5	26.2	27.2	27.7	27.1	26.8	26.2	27.0	25.8	Feb.	25.3
	1928-1929	26.8	27.0	26.9	24.6	25.5	26.7	27.3	27 2	24.5	25.5	25.8	26.6	Sept.	24.5
	1929-1930	27.9	25.6	26.7	25.4	28 5	26.8	26.7	26.2	26.0	26.1	27.9	26.8	April	25.4
	1930-1931	26.0	24.7	26.7	24.7	26.6	26.6	26.8	27.2	26.6	27.6	25.2	26.2	Feb. April	24.7
	1935-1936	27.6	24.7	22.7	24 8	25.9	25.8	24.4	26.6	27.6	26.2	25.9	27.1	Mar.	22.7
	Shortest time over 5 years	26.0	24 7	22.7	24.6	25 5	25.8	24.4	26 2	24.5	25 5	25.2	25.8		
III Section Azores to Bermuda	1927-1928	14.4	12.6	12.0	13.6	12 8	13.7	14.2	12.9	13.3	12.6	12.5	12.4	Mar.	12.0
	1928-1929	13.6	13.1	12.4	11.4	12.5	13.2	13.3	13.4	12.1	12.9	12 6	13.4	April	11.4
	1929-1930	12.9	11.2	12.5	11 4	13.4	13.8	12.4	13.5	12.5	12.7	13.1	12.5	Feb.	11.2
	1930-1931	12.5	11.1	12.1	11.8	13.7	12.5	13.8	12 8	12.1	12.1	11.8	11.4	Feb.	11.1
	1935-1936	13.8	12.1	11.2	12.1	12 9	11.8	11.8	12.1	12.1	11.4	11.4	12.9	Mar.	11.2
	Shortest time over 5 years	12.5	11.1	11 2	11.4	12.5	11.8	11 8	12.1	12.1	11.4	11 4	11.4		

Bermuda	Shortest time over 5 years	12.5	11.1	11.2	11.4	12.5	11.8	11.8	12.1	12.1	11.4	11.4	11.4	

TABLE IV.

COMPUTED TIMES OF PASSAGE OF AIRCRAFT FROM EAST TO WEST ACROSS THE NORTH ATLANTIC. (AIR SPEED 150 M.P.H.)

PERCENTAGE FREQUENCIES OF DEVIATIONS IN HOURS OF INDIVIDUAL TIMES FROM ANNUAL MEAN TIMES.

Route.	Year.	HOURS. −7	−6	−5	−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11
I	1927-1928				0.8	5.0	11.1	26.4	25.2	16.4	7.3	5.4	1.5	1.1						
	1928-1929		0.3	0.3	1.6	4.4	14.8	17.0	26.2	16.1	12.0	4.4	2.5	0.0	0.3					
	1929-1930			0.6	2.1	6.2	11.9	22.0	23.7	15.7	8.3	5.6	2.7	0.6	0.6					
	1930-1931			0.3	2.0	8.9	13.4	16.6	23.1	16.0	9.7	6.6	2.0	0.6	0.9					
	1935-1936			0.3	1.9	7.0	12.0	19.5	21.7	13.9	12.0	8.1	2.2	0.8	0.3	0.0	0.3			
II	1927-1928			0.7	2.7	9.3	10.6	19.2	22.3	13.0	12.3	4.8	2.7	1.0	0.7	0.0	0.7			
	1928-1929		0.3	1.2	2.3	5.0	11.1	14.6	26.5	19.8	10.5	5.2	2.0	1.2	0.0	0.3				
	1929-1930		0.3	0.9	2.3	6.3	11.9	15.6	27.0	16.5	10.5	5.1	2.3	0.9	0.0	0.0	0.3	0.3		
	1930-1931		0.3	1.4	5.1	5.9	12.4	15.2	23.4	14.9	9.0	5.1	3.4	2.0	0.6	1.1	0.3			
	1935-1936		0.3	1.1	4.4	6.4	11.6	16.9	21.0	15.5	13.3	5.2	2.5	0.6	0.6	0.3	0.6			
II Section Foynes to Botwood	1927-1928				1.4	5.5	14.0	19.2	27.4	14.7	12.6	2.7	0.7	0.7	1.0					
	1928-1929			0.3	0.6	7.0	9.0	17.0	26.5	26.0	8.7	3.2	0.6	0.9	0.0	0.3				
	1929-1930				0.9	4.3	12.8	18.2	27.6	20.5	11.1	2.8	0.9	0.6	0.3	0.3				
	1930-1931			0.3	1.7	5.4	13.5	17.7	26.2	18.6	8.2	4.5	1.4	1.4	0.8	0.3				
	1935-1936			0.3	1.9	6.1	12.2	17.4	27.3	19.9	8.3	3.0	1.7	0.6	1.1	0.3				
III	1927-1928			0.7	1.8	10.9	15.5	15.5	19.4	11.3	12.0	5.3	4.9	1.8	1.1					
	1928-1929		0.6	1.5	3.7	6.8	12.6	17.5	20.9	16.3	8.6	4.6	3.7	0.6	0.6	1.2	0.6			
	1929-1930			2.4	5.0	9.2	16.9	13.3	14.2	14.8	7.1	7.7	3.3	3.6	1.2	0.9	0.3	0.3		
	1930-1931		0.6	0.9	5.4	8.0	14.8	17.0	17.3	11.6	9.7	5.7	3.7	2.0	1.1	0.9	1.4			
	1935-1936	0.6	0.3	1.4	4.4	10.5	15.4	14.9	13.5	13.8	6.6	8.3	4.4	2.8	0.6	1.1	0.0	1.1	0.3	0.3
III Section Azores to Bermuda	1927-1928					1.4	6.7	25.7	32.0	23.2	7.0	3.2	0.4	0.0	0.4					
	1928-1929				0.3	1.8	6.8	23.4	33.5	22.2	7.4	4.3	0.3							
	1929-1930				0.6	2.4	9.5	26.3	23.4	20.7	11.2	5.3	0.0	0.3	0.0	0.3				
	1930-1931				1.1	3.1	6.0	32.7	23.0	18.7	6.3	4.5	2.0	1.4	0.9	0.3				
	1935-1936				0.3	6.3	6.3	38.6	16.8	12.1	11.6	2.8	3.0	1.1	0.8	0.0	0.3			

times of passage occur in the winter months and the shortest times in the spring. In the case of the direct route, however, both the longest and the shortest times occur in the winter. A rather surprising result is the close agreement between the Foynes-Botwood and Azores-Bermuda sections, the winds on the two routes having practically the same strength, even in the summer months.

The northern route stands out as being the most favourable from the point of view of winds. This is, perhaps, to be expected when it is considered that the route goes round to the north of the main Atlantic depression tracks and thereby largely avoids adverse head winds. The monthly mean times on this route are remarkably constant throughout the year. A similar constancy is observed in the monthly mean times on Route III from April to October, but here there is a marked rise in the winter months which reaches a maximum in January.

The table of percentage frequencies of deviations from the annual mean times (Table IV) is of interest in that it shows the extent to which a regular air service could be operated to schedule on any of the three routes. The results are, on the whole, encouraging, for they indicate that the times are generally within $2\frac{1}{2}$ hours of the annual mean times on 80 per cent. of occasions or more except on Route III where the percentage is 70.

TABLE V.

Summary of Times of Passage and Ground Speeds.

Air speed = 150 m.p.h.

Route.	I.	II.		III	
	Foynes to New York *via* Greenland.	Foynes to New York *via* Botwood.	Section Foynes to Botwood	Foynes to New York *via* Azores.	Section Azores to Bermuda.
Average of all times of passage (hrs.)	24.7	23.4	14.8	30.5	15.1
Corresponding ground speed (m.p.h.)	146	137	135	137	136
Average head wind (m.p.h.)	4	13	15	13	14
Shortest time (hrs.)	18.6	17.6	10.0	22.7	11.1
Corresponding ground speed (m.p.h.)	194	177	200	184	185
Average following wind (m.p.h.) ...	44	27	50	34	35
Longest time (hrs.)	31.4	32.6	22.2	41.3	21.8
Corresponding ground speed (m.p.h.)	115	98	90	101	89
Average head wind (m.p.h.)	35	52	60	49	61
Percentage number of occasions corresponding to head wind of more than 40 m.p.h.	—	1.2	2.8	0.9	2.3
Number of days a year	—	4	10	2	8

Table V gives a summary of the most important times from which the corresponding ground speeds and equivalent average head winds have been calculated. The maximum average head wind on the Foynes-Botwood section is 60 m.p.h. while that on the Azores-Bermuda section is of the same order. Table IV has been used to obtain the number of occasions on which a head wind of more than 40 m.p.h. would be experienced, the result being 10 days a year in the case of the Foynes-Botwood section and 8 days a year on the Azores-Bermuda section. These results are in close agreement with those obtained in the earlier investigation

and justify the conclusion already drawn with regard to the specification of range of trans-Atlantic aircraft.

In discussing the remaining meteorological factors which have a bearing on the operation of trans-Atlantic air routes, it will be convenient to deal with each route as a whole rather than to take each meteorological element separately. Considering first the Northern Route, the main difficulties to be overcome will be due to fog, snow, ice accretion and ice-bound harbours in winter. The area to the south of Greenland is one of strong cyclonic activity, depressions passing northwards throughout the year either up Davis Strait to the west or Denmark Strait to the east, though they seldom penetrate the interior over the ice cap. Along the route to Greenland, cloud is frequent at all seasons and in the winter months conditions favourable for ice accretion are likely to be common in the maritime air masses which circulate round depressions approaching Greenland. Over the ice cap itself the winter months are frequently clear and there is little risk of ice accretion.

Over the sea and round the coasts of Greenland fog is common in the summer months. The distribution varies from place to place, the south and west coasts being the foggiest. The fogs are confined largely to the sea and open coasts, the frequency diminishing with distance from the sea. Thus Godthaab on the west coast has 61 days of fog a year while Kornok, which is about 40 miles up the inlet, has only 17 days a year. In winter when the ice has formed, fogs are rare and the weather is frequently settled with clear skies.

An important feature of Greenland weather is the occurrence of strong katabatic winds which blow down from the ice cap, frequently with the force of a strong gale, laden with heavy drift snow and reducing visibility to a few yards. These winds often spring up suddenly and sometimes last for two days. They blow right down to the coasts and out to sea so that they are liable to affect harbours or refuelling bases. Drifting snow in strong winds is the main cause of bad visibility apart from fog, and occurs over the ice cap as well as on the coasts.

Ice conditions vary considerably. The East Greenland pack arrives at Cape Farewell in January and begins to advance up the west coast, which is usually ice-bound from April to September as far north as Godthaab. North of Godthaab to Disko Bay is relatively ice-free, but the bays and harbours begin to freeze in November. Open water reappears in May and widens throughout the summer.

The coast of Labrador is affected by ice of the Davis Strait pack which drifts southwards reaching the north-east coast in November. At the same time the harbours begin to freeze and fast ice forms along the coast, which does not usually become navigable until July.

Turning now to the direct route, the main meteorological considerations are again fog, snow, ice accretion and ice-bound harbours in winter. The area of the Grand Banks is one of the foggiest in the world, the fogs reaching their maximum in the early summer, when the frequency rises to nearly 50 per cent. It is probably this fact which has given Newfoundland itself the reputation of being a foggy country. Until recent years, no reliable observations of visibility were available from inland stations in Newfoundland. In 1935, however, the Meteorological Service of Canada undertook to provide the meteorological service required in that country for the projected trans-Atlantic air service and a network of reliable meteorological stations has since been established. The map in Fig. 3 shows the number of days of fog at the different stations observed during the year August, 1937-July, 1938. Lines of equal frequency have been drawn for intervals of 5 days. While these must be regarded as approximate, it is clear from the map that fogs are largely confined to the coasts and do not extend appreciably to inland districts, where the frequency is generally less than 5 days a year. The fogs which occur inland are of the normal radiation type, reaching a maximum in the early morning, after which they disperse.

The entire extent of the direct route is characterised by large cloud amounts at all seasons of the year, the cloudiness increasing from east to west. Considerable cyclonic development occurs in the winter months in the Greenland-Iceland region with associated frontal activity over the North Atlantic. In the direct or maritime polar air masses which predominate over the western half of the route the freezing level will occur at no great height and will become progressively lower towards Newfoundland. In these circumstances ice accretion is likely to be sufficiently serious to constitute a definite hazard in the operation of aircraft.

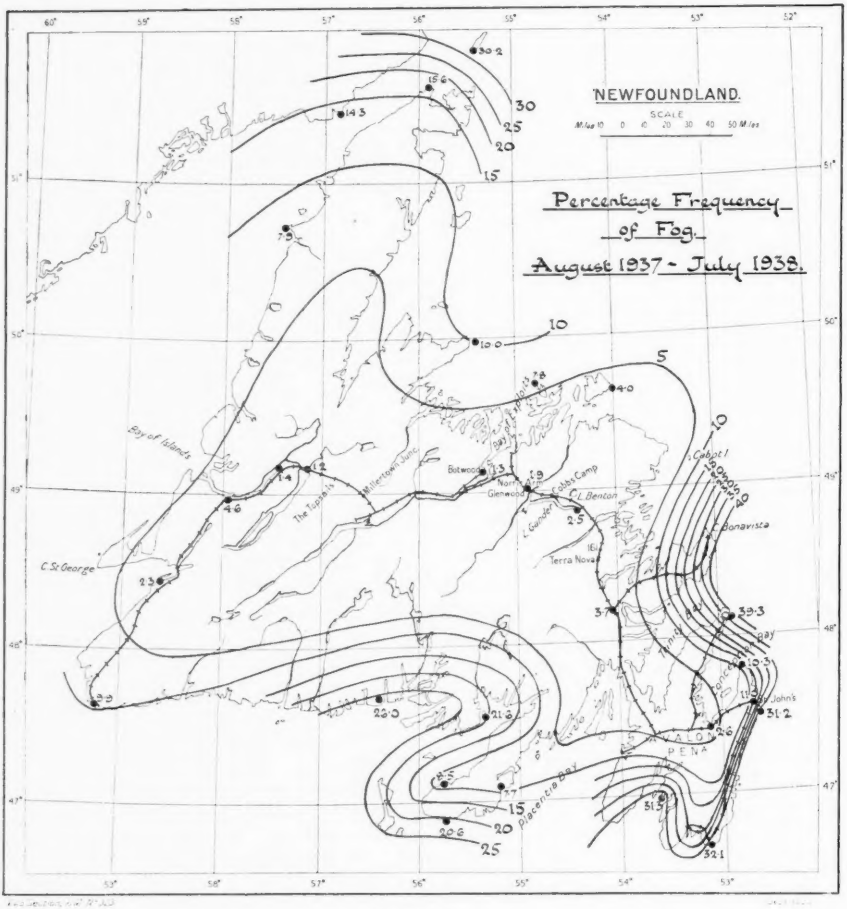


FIG. 3.

Over the greater part of Newfoundland snow is confined to the months October-April, the heaviest falls occurring between December and March. In January snow falls on an average of about one day in two. In the extreme north, however, snow is liable to occur in any month, although amounts are small in June, July and August. The heaviest falls occur in the south-west. From the latter part of December until the middle of April the ground is continuously snow covered over the whole of Newfoundland.

Arctic ice drifts southward in the Labrador current and usually reaches the neighbourhood of Belle Isle late in December, and the Cape Race area late in January. The ice usually breaks up on the southern part of the coast about the middle of April. Early in May the boundary of the pack ice has receded to the north of the Grand Banks and towards the end of June the east coast of Newfoundland is clear. At Botwood, which was used as the base for the survey flights in 1937, ice usually commences to form at the end of November or early in December. In some years it melts again and re-forms at a later date; in 1926, for example, after forming on December 12th, it melted twice and re-formed between that date and January 22nd. The ice usually clears completely between April 20th and May 10th, although it has been known to clear as early as April 9th. It is not safe to count on the bay being clear after the middle of November until the middle of May, so that for six months it cannot be used for flying boat operations.

The southern route is not only free from the hazards of fog and ice, but weather conditions generally are much better than on either the northern or the direct route, especially during the summer half year. At Horta the sky is half clouded on two days out of three, the height of the cloud base being usually 2,000-3,000 feet above sea level; it rarely falls below 1,000 feet. Fog is rare and seldom persists. Strong winds are, however, frequent. Winds of force 10 and above normally occur on 1-2 days in each month from October to March, while winds of speeds above 47 m.p.h. occur on 1 day in 18 throughout the year. A wind of 107 m.p.h. has been recorded on one occasion. Thunderstorms occur on about one day a month from October to April, and more rarely during the summer months. At Bermuda fog is practically unknown and cloud amounts are rather less than at the Azores. The average height of cloud base is similar to that at Horta. Gales are rare, occuring only once in two or three years in each of the months September-March. Thunderstorms occur, on an average, on 3-4 days a month in July, in August and on one day a month in most other months. They are least frequent in December and January.

During the months June-November, the Bermuda-New York section of the route is liable to be affected by tropical cyclones which form normally in the region between the Cape Verde Islands and the Caribbean Sea. They move initially in a west-north-westerly direction and then recurve over the Gulf of Mexico or near the West Indies, finally moving north-eastwards across the North Atlantic. The average number experienced per year is three or four, of which one or two may be expected to cross the route. September is the month in which they are most likely to occur. They are, however, easily identified and their movement can be forecast before they arrive near the route.

The foregoing comparison of the prevailing meteorological conditions along the three routes points to the fact that although, compared with the other two routes, the northern route offers certain advantages, such as short stages and comparative freedom from adverse winds, any attempt to establish a regular air service would be attended by too many difficulties in the present state of aeronautical development. In any case flying boats could only be operated during a relatively short period of the year on this route. From the meteorological point of view, further detailed investigation would be necessary of the conditions which prevail along the route and particularly at possible bases or refuelling points in Greenland, before any project could be considered.

The direct route has the advantage of being the shortest of the three routes and, from a consideration of the meteorological conditions and the experience gained during 1937, there does not appear to be any reason why a scheduled service should not be operated with success, at least during the summer half year. As in the case of the northern route the freezing of harbours in the winter precludes the use of flying boats during that season and the only prospect of operating an all-the-year-round service appears to be by means of landplanes. This, however, presupposes that the runways on the aerodrome in Newfoundland can be kept sufficiently clear of snow for aircraft to land and take-off and also that the hazard of ice accretion can be overcome.

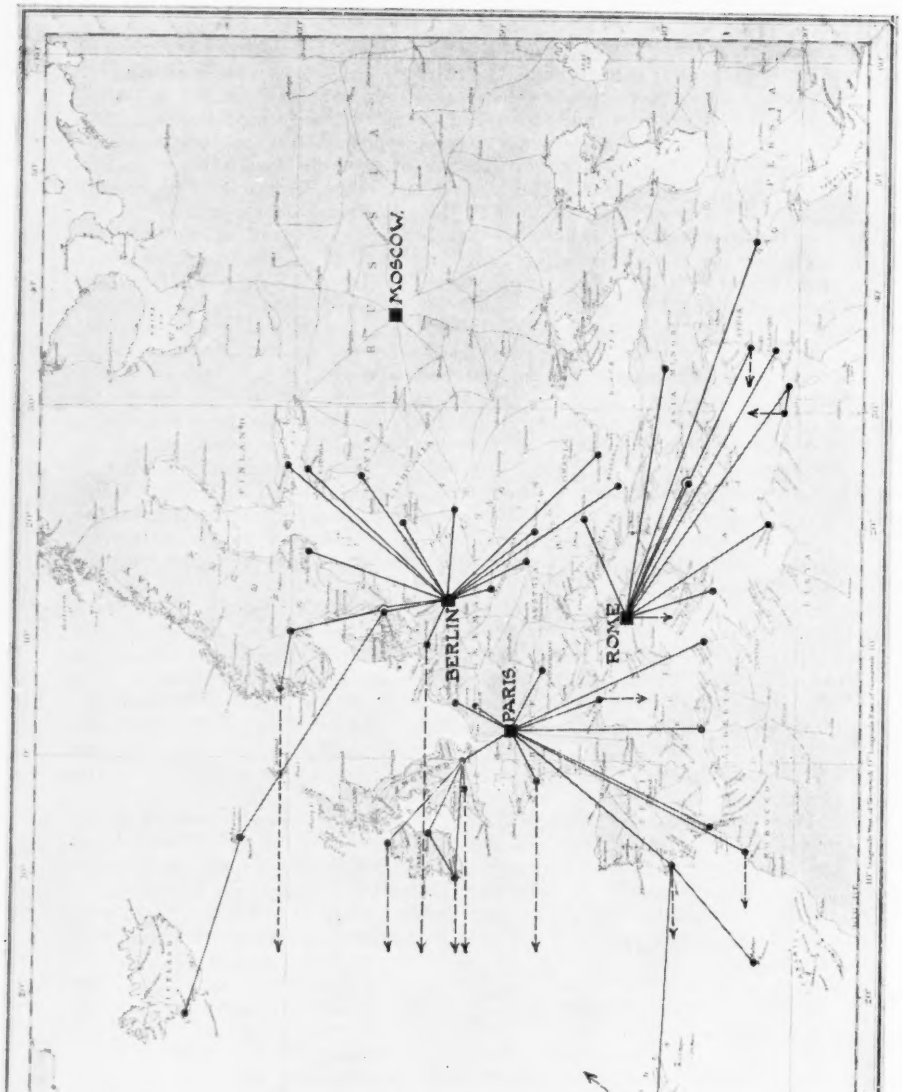


FIG. 4.
Dissemination of Meteorological Information in Europe.

The southern route is the only one which offers immediate prospects of the establishment of an all-the-year-round service, but even this route is not without its difficulties. Owing to the topography of Horta and the varying conditions of wind and swell, it would appear that there is difficulty in selecting a site for a flying boat base which can be operated under all conditions of wind and weather. There is no aerodrome in the Azores at present, but it is understood that a possible site is being surveyed. Further experience may show that the use of landplanes is the only feasible means of operating the southern route. If this should prove to be the case and both the ice accretion problem on the direct route and the question of winter landings in Newfoundland are successfully settled, the direct route, which has many other obvious advantages, would appear to be the best for a regular air service between this country and North America.

Meteorological Organisation for Trans-Atlantic Flights.

It will be evident from what has been said, both with regard to the general problem of trans-oceanic flying and to the meteorological conditions which exist over the North Atlantic, that the inauguration of a trans-Atlantic air service must be preceded by the establishment of a specialised meteorological organisation capable of supplying the fullest possible information to the operating personnel. An organisation was drawn up before the survey flights of 1937 and proved satisfactory. On the basis of the arrangements thus made, a detailed organisation was agreed upon in March of this year at a conference held in Dublin between representatives of Great Britain, Eire, Canada and the United States. Before proceeding to give an outline of this organisation it may be of interest to refer briefly to the arrangements which exist in Europe for the dissemination of the meteorological data used in the preparation of weather charts, which form the basis of weather forecasting and of the meteorological information supplied for air navigation; and also to the arrangements for the exchange of these data with North America.

The European system involves the broadcasting at fixed hours by four high power radio stations of collective messages containing observations in an international code from a close network of stations. The observations are made at fixed times—the principal observations at 01.00, 07.00, 13.00 and 18.00 hours G.M.T. with intermediate observations at 04.00, 10.00, 16.00 and 22.00 hours G.M.T. They are collected in each country by the central meteorological office which transmits them as a collective message to the main broadcasting station. Paris acts as transmitting station for Western Europe and North Africa, Berlin for Central Europe and Scandinavia, Rome for the countries of the Central and Eastern Mediterranean, and Moscow for the U.S.S.R. The organisation is shown schematically in Fig. 4. The maritime countries of Europe also receive by radio reports from their national ships made at fixed times (indicated by broken lines on the map) and these are included in the collective messages as well as aerological observations from certain stations. British selected ships send observations four times a day to London when east of longitude 40° and also send certain observations to Toronto or Washington when west of that meridian. Weather observations from stations in Europe and North America are interchanged twice daily. Rugby is the transmitting station for Europe in this case and issues a selection of European observations made at 07.00 and 18.00 hours G.M.T. in an international abbreviated code. Arlington transmits observations made at 01.00 and 13.00 hours G.M.T. at stations in North America and reports from ships in the western North Atlantic. Fig. 5 illustrates this side of the organisation. It is possible for any meteorological service in Europe to prepare a new weather chart, covering Europe and the Mediterranean, every three hours. While this intensity of reports is necessary for the issue of meteorological information for aviation purposes in Europe it is not so essential to have the same frequency of observations as a basis of the trans-Atlantic organisation, since the base meteorological service is concerned

Fig. 4.—*Dissemination of Meteorological Information in Europe.*

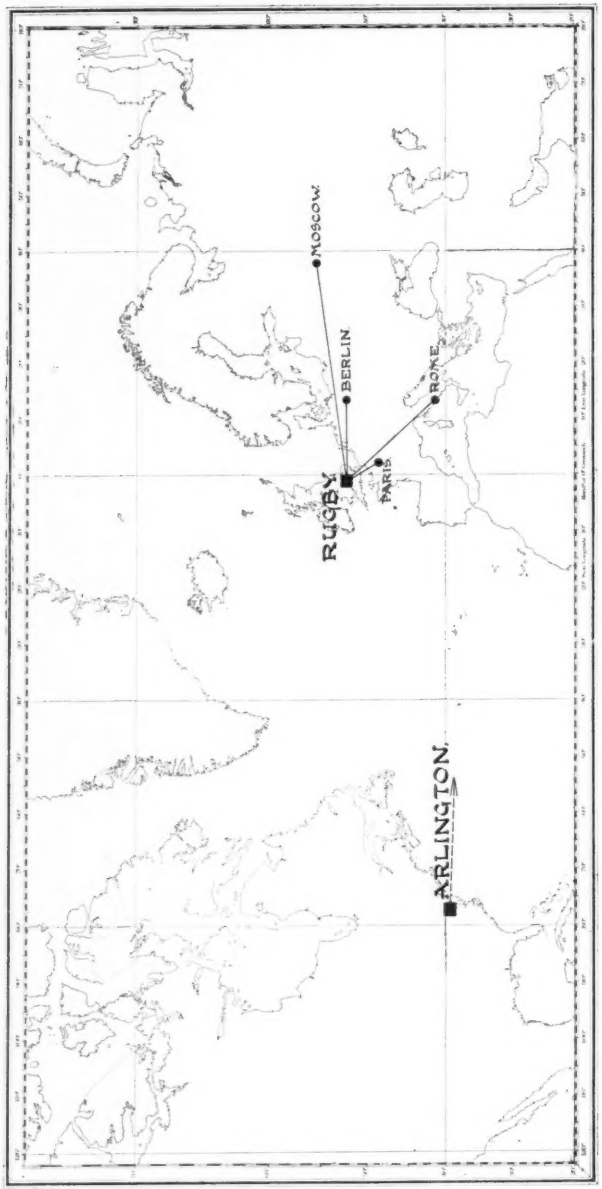


FIG. 5.

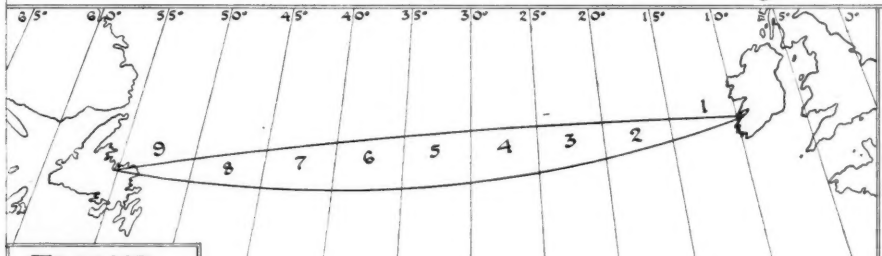
Interchange of meteorological information between Europe and North America.

TRANS-NORTH ATLANTIC AIR ROUTE – FOYNES to BOTWOOD.

Meteorological Report issued on {1800 / 0100} G.M.T. Chart 14th–15th August. 1937.

Company Imperial Airways. **Aircraft** Caledonia **Captain** A.S. Wilcockson.

Scheduled Time of Commencement of Flight 0400 G.M.T. **Track** Great Circle.



General Situation at 0100 G.M.T. over North Atlantic.

1. A shallow depression between Iceland and Greenland is filling up.
2. A feeble ridge of high pressure over Ireland is moving east in advance of a small and shallow depression centred at approximately 51°N, 13°W; this depression is moving slowly southeast.
3. A depression centred at approximately 58°N, 54°W is moving slowly eastnortheast. The associated warm front extends from near the centre through 55°N, 37°W to 50°N, 22°W whilst the cold front passes through 55°N, 48°W, 45°N, 58°W. The warm front is moving eastnortheast 15/20 m.p.h., whilst the portion of the cold front over and north of Newfoundland is moving east 20 m.p.h.
4. A feeble ridge of high pressure is moving east behind the cold front, and will give west to northwest winds over and immediately to the east of Newfoundland during the next 24 hours.

FLIGHT FORECAST.		Foynes to Loop Head.	Zone 1.	Zone 2.	Zone 3.	Zone 4.	Zone 5.	Zone 6.	Zone 7.	Zone 8.	Zone 9.	Botwood.
TIME (G.M.T.)		0415	0545	0720	0855	1045	1245	1445	1645	1840	2050	
Distance from Foynes (nautical miles)		30	215	400	585	770	955	1140	1325	1515	1738	
WIND *	Surface.	Calm	Light, variable	Light, variable	W.S.W., 10 mph, backing to S.S.W 15 m.p.h.	S 15/20 m.p.h. veering at warm front to W 20/25 m.p.h.	WSW, 15/20 m.p.h.	WSW or SW 15/20 m.p.h.	SW, 15/20 m.p.h. veering to W. at cold front.	W. 15 m.p.h.	W. 15 m.p.h.	W. 15 m.p.h.
	2,000 feet.	270° 10 m.p.h.	180° 10 m.p.h.	270° 10 m.p.h.	260° 10/15 m.p.h. backing to 200° 15/20 m.p.h.	200° 20 m.p.h. veering at warm front to 230°, 30 m.p.h.	260° 35 m.p.h.	250° 30/35 m.p.h.	250° 30/35 m.p.h. veering at cold front to 290° 30/35 m.p.h.	270° 25 m.p.h.	280° 25 m.p.h.	280° 20/25 m.p.h.
	5,000 feet.		210° 10 m.p.h.	280° 15 m.p.h.	270° 15 m.p.h. backing to 220° 20 m.p.h.	220° 20 m.p.h. veering at warm front to 280°, 30 m.p.h.	270° 35 m.p.h.	260° 35 m.p.h.	260° 35 m.p.h. veering at cold front to 280° 30/35 m.p.h.	270° 25 m.p.h.	280° 25 m.p.h.	
	..... feet.											
WEATHER		Fair	Fair	Cloudy	Overcast; rain.	Overcast; intermittent rain or drizzle. Fog patches.	Overcast; intermittent rain or drizzle. Fog patches.	Overcast; intermittent rain or drizzle. Fog patches.	Showers near cold front, followed by gradual improvement with decreasing cloud.	Fair	Fair	Fair
CLOUD LOW	Type and Amount.	Sc. 3/10 – 7/10	Sc. 5/10 – 8/10	Sc. 5/10 – 8/10	Ns. 10/10	Ns, Sc, St. 10/10	Ns, Sc, St. 10/10	Ns, Sc, St. 10/10	Ns and Cb. 10/10 near cold front, then Cu, Cb, Sc in variable amounts	Sc and Cu, 4/10 – 7/10	Sc and Cu, 3/10 – 5/10	Sc and Cu, 3/10 – 4/10
	* Height of Base.	2,000' – 3,000'	2,000' – 3,000'	1,500' – 2,500'	300' – 600'.	0 – 1,000'	0 – 1,000'	0 – 1,000'	500' to 1000', then lifting gradually.	2,000' – 3,000'	2,000' – 3,000'	3,000' – 4,000'
	* Height of Tops.	3,000' – 4,000'	3,000' – 4,000'	3,000' – 4,000'.	6,000' at first becoming 10,000' – 12,000'	4,000' – 6,000'	4,000' – 6,000'	4,000' – 6,000'	6,000' – 8,000	5,000' – 6,000'	4,000' – 6,000'	5,000' – 6,000'.
	MEDIUM	Nil	Nil	Ac. and As.	As.	As.	As.	As.	Ac.	Ac.	Nil	Nil.
	HIGH	Ci. and Cs.	Ci. and Cs.	Ci. and Cs.	Ci. and Cs.	Ci.	Ci.	Ci.	Ci.	Nil	Nil	Nil.
VISIBILITY		Over 12 miles.	Over 12 miles	Over 12 miles at first but deteriorating	1 to 2 miles	Fog patches	Fog patches	Fog patches.	Fog patches with visibility improving behind cold front to over 12 miles.	Over 12 miles	Over 12 miles	Over 12 miles.
ICING		–	–	–	In clouds near or above 10,000'	–	–	–	Slight in cloud tops.	–	–	–
STATE of SEA and SWELL		Slight.	Slight.	Moderate	Moderate	Rather rough.	Moderate	Moderate	Moderate	Moderate	Moderate	Slight.
REMARKS.						Warm front will be crossed at 26° W. Low cloud extending down to surface in fog patches.			Cold front will be crossed at 41° W.			

* All heights are above M.S.L.

Meteorological Office, Foynes. 15th August 1937. Issued at 0315 G.M.T. S.P. Peters. Meteorological Officer.

FIG. 6.

Specimen meteorological report issued to Commander of trans-Atlantic aircraft.

with the more general problem of the distribution of wind and weather over a wide area. The present organisation by which a weather chart covering North America, the Atlantic and Western Europe can be prepared only twice daily is not, however, sufficient. It will be necessary for the meteorological service at the trans-Atlantic base to prepare complete weather charts of the North Atlantic, including the Polar Regions and the whole of the North American Continent, every six hours, in order that a complete analysis may be made of the meteorological situation over the Atlantic and of the changes in progress. Before the survey flights commenced in 1937, provisional arrangements were made for the meteorological services at the Shannon and Newfoundland bases to complete the network of reports by interchanging collective messages containing observations from stations in Western Europe and Eastern North America respectively together with ships' observations. The general question of arranging for the regular exchange of information between Europe and North America every six hours will have to be settled by international agreement, however, before regular trans-Atlantic flying commences.

Turning now to the actual flight organisation, it may be mentioned that during a flight the aircraft is in continuous radio communication with the airport of departure until it is approximately halfway across the Atlantic when control is transferred to the terminal airport, provided that satisfactory two-way communication has been established. The two bases are also in direct communication and for the purpose of passing meteorological information to the aircraft, the transfer of responsibility is made invariably when the aircraft reaches longitude 30° W.

When a flight is due to take place the Meteorological Office at the airport of departure requests the Meteorological Office at the terminal airport to commence the transmission of special meteorological information and, as soon as practicable, notifies that service of the track to be followed, the probable flying height or heights and the aircraft's E.T.A. at 30° W. and at the terminal airport. The meteorological staff at the terminal airport then prepare a message for transmission to the airport of departure on the basis of the most recent weather chart. This message consists of a statement of the meteorological situation over the second half of the route and adjacent land areas, and of anticipated developments, together with a forecast of the meteorological conditions at the terminal airport covering a period of 12 hours from the time of issue. A similar analysis message, referring to the first half of the route, is prepared at the airport of departure for transmission to the terminal. Similar messages are prepared and interchanged as soon as possible after the completion of each synoptic weather chart, that is, at intervals of six hours. To the last message issued from the terminal airport before the flight is added a forecast for that portion of the route lying between longitude 30° W. and the terminal, covering the period during which it is anticipated that the aircraft will be flying over that section. This message is transmitted so that it arrives at the airport of departure not later than three hours before the E.T.D. of the aircraft. The transmission of similar messages to the airport of departure, based on each six-hourly chart, is continued during the flight until the aircraft has passed 30° W.

Before a flight takes place a conference is held in the Meteorological Office at which the Commander of the aircraft, the Control Officer, and the Duty Meteorological Officer are present, and at which the meteorological outlook is discussed and all relevant information supplied. A detailed route forecast covering the period of the flight is available not later than six hours prior to the commencement of the flight. This is intended to enable the commander of the aircraft to make his flight analysis and decide on the track he will follow and the altitudes at which he will fly, and to calculate the time which will be required to complete the flight.

Approximately two hours before departure a complete report is handed to the pilot, giving a statement of the general situation over the North Atlantic, a

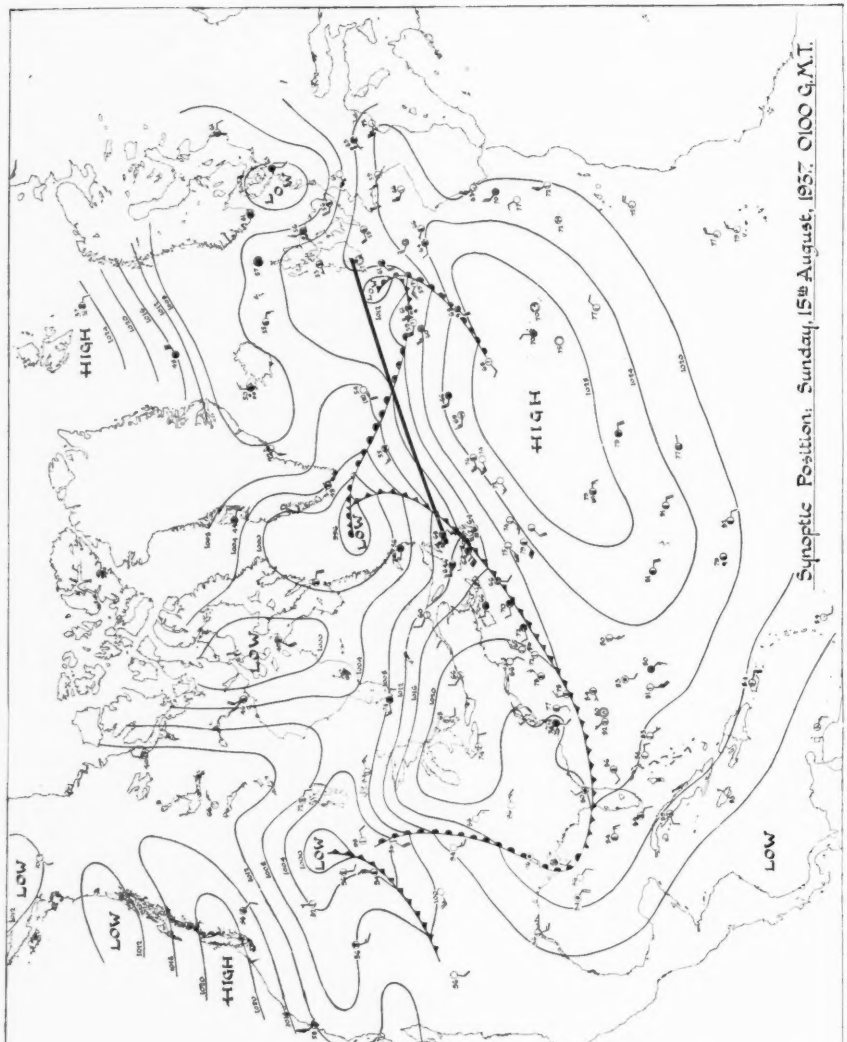

Synoptic Position: Sunday, 15th August, 1937. 0100 G.M.T.
HIGH
LOW
LOW
HIGH
LOW
LOW
HIGH
LOW
LOW

FIG. 7.

detailed forecast for the whole route for the period of the flight and a forecast of conditions at the terminal at the estimated time of arrival. This is accompanied by a copy of the latest synoptic weather chart of the North Atlantic. A repetition of this forecast is transmitted to the terminal airport for the information of the meteorological staff there. A specimen form detailing the information supplied at the Shannon Air Base on the occasion of the flight of the " Caledonia " on the 15th August, 1937, is shown in Fig. 6. For convenience the information is not prepared on one form, but a separate sheet is used for each 5° zone, the sheets being bound with the weather chart in book form.

After the aircraft has left, further meteorological advice is sent regularly to the Commander, prepared on the basis of each new six-hourly chart. The information includes a statement of developments in the meteorological situation over the North Atlantic with reference to the chart supplied before departure, any necessary amendments to the route forecast supplied before the flight, and an estimated value of the sea level pressure in the vicinity of the aircraft. All meteorological messages addressed to the aircraft in flight are repeated to the Meteorological Office at the terminal airport.

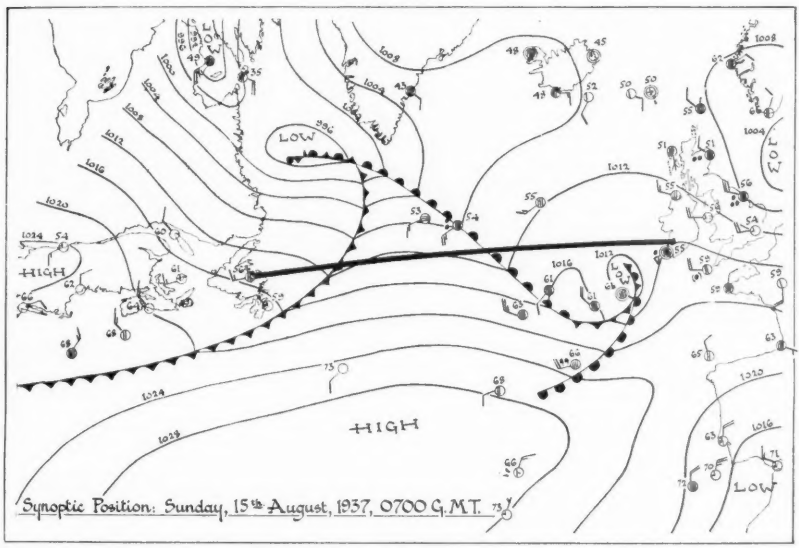
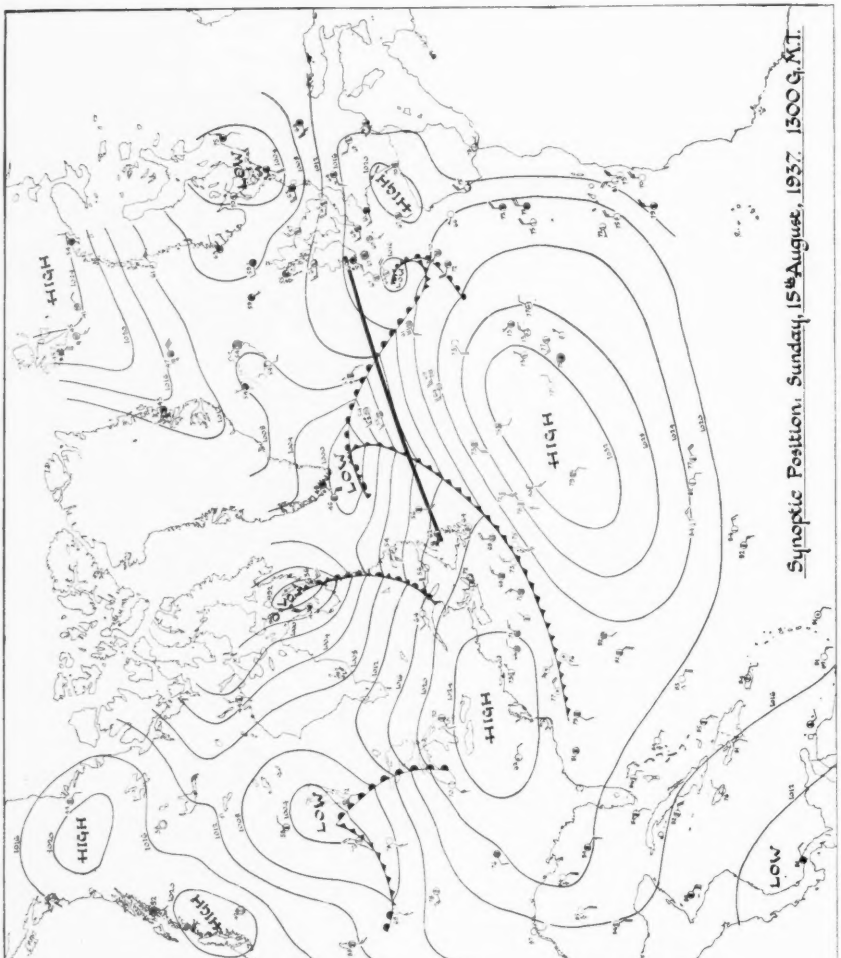


FIG. 8.

After the control of the aircraft has been transferred to the terminal airport the supply of meteorological information is effected by the Meteorological Office at the terminal, on exactly the same lines as those just described. The information is supplemented by reports of existing weather conditions in the vicinity of the terminal airport and also, if necessary, at alternative alighting areas, which are transmitted to the aircraft hourly. Two hours before the estimated time of arrival, a report of upper wind observations at the terminal base is also transmitted to the aircraft and finally, 20 minutes before the E.T.A., a landing report is sent.

During the course of the flight meteorological and position reports are prepared by the navigating officer of the aircraft and transmitted in a standard form to the base every hour. These reports include details of the air temperature and wind at flying height, the types, amounts and heights of cloud above and below the


Synoptic Position, Sunday, 15th August, 1937. 1300 G.M.T.
HIGH
LOW
HIGH
LOW
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HIGH
LOW
HIGH
LOW

FIG. 9.

aircraft, the general weather conditions, turbulence and visibility. The reports from the aircraft are of considerable assistance to the meteorologist at the base, in that they enable him to keep a check on his forecasts and to follow developments; they form an essential feature of the meteorological organisation.

Similar organisations to that described are brought into operation on the remaining sections of the trans-Atlantic route: Southampton-Shannon, Botwood-Montreal and Botwood-New York via Shediac. The meteorological organisation has been devised with a view to providing essential safeguards and the maximum help to navigation which is possible with the means available.

Figs. 7 to 9 show the weather situation during the flight of the " Caledonia " to which the report in Fig. 6 refers. The most important feature of the 01.00 G.M.T. chart, on which the final forecast was issued before the commencement of the flight, was the extensive warm sector associated with the depression centred between Greenland and Labrador. It was anticipated that the aircraft, flying on the great circle track, would have to fly through a belt of warm air over 500 miles in width after having traversed the warm front. Compensating features of the situation were the weak pressure gradient and consequently light winds which would be experienced between the Shannon and longitude 25° W. and the favourable landing conditions which would exist at Botwood in the polar air behind the cold front by the time the aircraft arrived.

The " Caledonia " left the Shannon at 04.30 G.M.T. and flew at heights varying from 200 to 2,500ft. thereby avoiding the stronger adverse winds which would have been encountered at a higher altitude. The duration of the flight was 16h. 44m. (The longest time taken on an east-to-west flight during the series was 17h. 45m. and the shortest time 14h. 25m.)

In advance of the warm front there was a belt of low cloud about 150 miles in extent, with base generally about 600ft. and continuous rain. Throughout the warm sector continuous layers of low cloud with base mostly about 500ft. were encountered. Rain and sea fog were frequent. Conditions improved after flying through the cold front and were described by the Commander as " perfect " on arrival at Botwood.

FIG. 9.

APPLICATION OF METEOROLOGICAL INFORMATION.

In the meteorological information supplied prior to a trans-Atlantic flight the wind forecast, as mentioned earlier, is of fundamental importance. It will have been observed that the forecast is given for each 5° zone; this enables the Commander to prepare his flight schedule and to determine the various courses on which he will fly over different sections of the route. When actually in flight, the radio direction finding service comes into operation and enables the navigator to maintain a constant check on his position. As an example of the application of wind data supplied prior to the commencement of the flight, mention may be made of the first double survey flight made on the night of the 5th/6th July, 1937, by the Imperial Airways " Caledonia " and Pan-American Airways " Clipper III." Had the aircraft left the Shannon and Botwood at the same time the " Clipper " would have arrived at the Shannon some hours earlier than the " Caledonia " arrived at Botwood since there was westerly wind blowing over the entire route and the cruising speeds of the two aircraft were approximately equal. The times of departure were adjusted on the basis of the meteorological forecasts so that the two aircraft should arrive at their respective destinations as nearly as possible at the same time. Actually they landed within ten minutes of each other.

A second example is given in Table VI which compares the estimated and actual times of flight from the Shannon to Botwood of " Caledonia " on August 15th, 1937, the estimated time being computed from the wind forecast included in the report given in Fig. 6. It will be seen that the computed time agreed to within six minutes with the actual time taken.

TABLE VI.

COMPARISON OF ESTIMATED AND ACTUAL TIMES OF FLIGHT FROM SHANNON TO BOTWOOD OF "CALEDONIA," AUGUST 15, 1937

(ESTIMATED TIME COMPUTED FROM FORECASTED WIND BEFORE COMMENCEMENT OF FLIGHT.)

(ASSUMED AIR SPEED 125 KNOTS.)

Zone	Foynes-Loop Head.	10°-15°W	15°-20°W	20°-25°W	25°-30°W	30°-35°W	35°-40°W	40°-45°W	45°-50°W	50°W-Botwood	Computed Time	Actual Time
Track	278°	278°	275°	272°	268°	263°	260°	255°	251°	246°		
Distance (nautical miles)	30	193	179	178	180	179	188	192	199	246		
Forecasted wind (speed in knots)	270° 9	180° 9	270° 9	230° 13	240° 22	260° 30	250° 28	265° 28	270° 22	280° 22		
Course	278°	273°	275°	268°	263°	263°	258°	257°	255°	252°		
Ground speed (knots)	116	125	116	115	105	95	97	97	104	106		
Time (minutes)	16	93	93	93	103	113	117	119	115	139	16h. 41m.	16h. 47m

Reference was made earlier to the possibility of a trans-ocean pilot varying his course in order to take advantage of favourable winds or to avoid strong head winds. An example of this type of navigation is afforded by the ten flights of the airship "Hindenburg" between Frankfort and New York in 1936. Fig. 10 shows the courses followed both on the outward and return flights. The outward flights indicate considerably greater deviation from the great circle track than the return flights. An outstanding case is that of the fourth flight

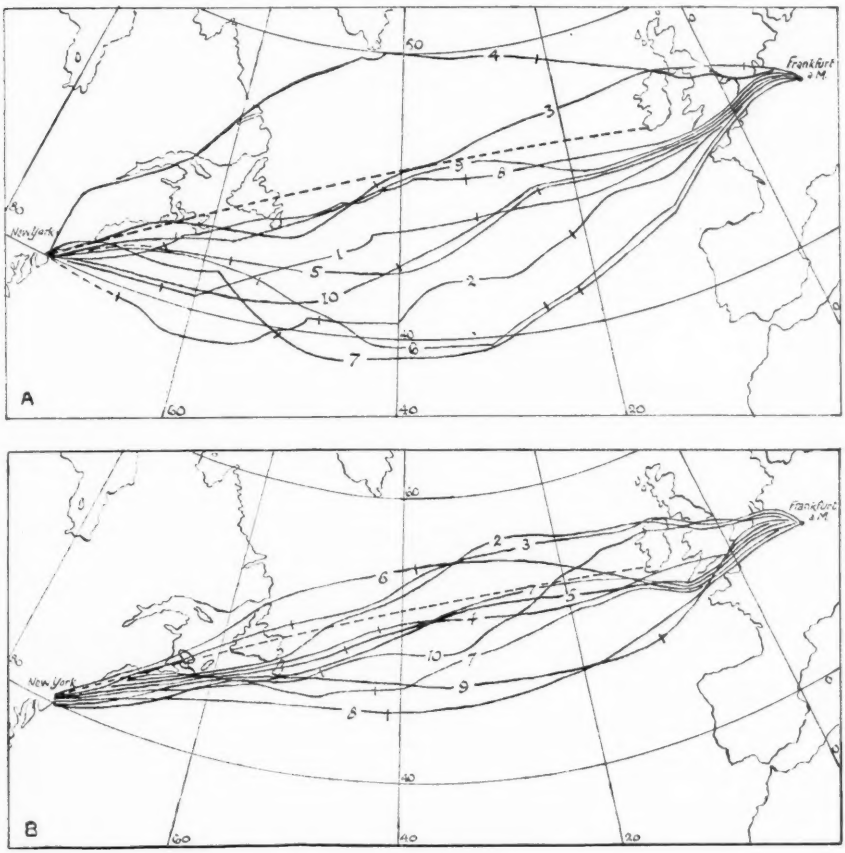

FIG. 10.

Maps showing courses followed by the airship "Hindenburg" between Frankfurt and New York, May-October, 1936.

(a) Outward flights.
(b) Return flights.

between the 30th June and the 2nd July. Although the course deviated to such an extent from the great circle track, the time taken to complete the flight was the shortest of the series. A course was taken on the north side of the North Atlantic trough of low pressure with areas of low pressure, one between Ireland and Newfoundland extending northwards towards Greenland and a second over

Labrador. This distribution gave strong easterly to north-easterly winds in the Davis Strait; on part of the course there was an E.N.E. wind of 100 m.p.h.

This type of navigation is, of course, far more practicable with an airship than in the case of heavier-than-air craft, but even with the latter it can frequently be practised with advantage. During the flight of "Caledonia" from the Shannon to Botwood on the night of 13th-14th September, 1937, a departure from the orthodox great circle and rhumb-line tracks was made on the basis of the information supplied by the Meteorological Office at the Shannon airport. An anticyclone over mid-Atlantic, which on the 12th was lying very near the rhumb-line track, would have provided very favourable conditions for a flight along that track had conditions remained stationary. It was anticipated, however, that the anticyclone would move southwards and that the westerly gradient to the north of it would strengthen. In consequence, Captain Wilcockson followed a rhumb-line course from the Shannon to a point 48° 30′ N., 25° W., and thence a rhumb-line course to Botwood. In this way he avoided the strong head winds which developed on the direct rhumb-line track and was able to take advantage of the lighter winds near the centre of the anticyclone. In spite of the greater distance travelled, the flight was accomplished in 15 hours 38 minutes, whereas it was computed that the crossing by the direct rhumb-line track would have taken more than 17 hours.

Choice of Altitude for Flying: Upper Wind Observations.

The variation of wind speed and direction which occurs with height is an important factor in trans-oceanic flying, from the point of view of reducing times of flight and economising fuel. Over the North Atlantic variations of wind at different altitudes are not generally so marked as in some other parts of the world, *e.g.*, the trade wind regions where winds from opposite directions frequently occur at different heights. Nevertheless, they are of sufficient importance to be taken into account when planning a flight. The problem is not a simple one, for the time required and fuel expended in climbing to a given altitude and also the most economical height from the point of view of engine performance are factors which have also to be taken into consideration.

German flying boats on the southern North Atlantic routes have sometimes endeavoured to minimise the effect of a strong head wind by flying at a few feet above the water, in order to obtain an increase in lift from the rising air over the crest of the waves (see Fig. 11).* These upward currents, occurring at very

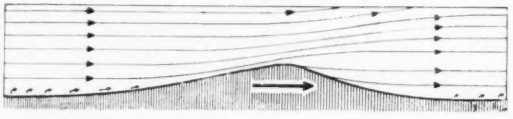

Fig. 11.
Upward motion of air due to wave.

short intervals, impart an upward impulse which can be converted into an increase in speed. It is claimed that an increase of about 6 m.p.h. is obtained in this way in favourable conditions. It is doubtful, however, whether this method would commend itself to the majority of pilots, especially those carrying passengers.

An investigation into upper winds over the North Atlantic based on observations made from ships at different times indicates that westerly winds predominate up to at least 15,000 feet, the frequency of winds from this direction increasing

* Figs. 10 and 11 have been taken from Annalen der Hydrographie, 1938. Heft 1. (H. Seilkopf: "Oceanflug und Hohenwetterdienst").

with increasing height. The frequency of winds with an easterly component is less than 15 per cent. at all heights up to 15,000 feet; winds from this direction are more frequent in spring than at any other season. The frequency of winds of over 30 m.p.h. increases from 14 per cent. at 2,000 feet to 44 per cent. at 15,000 feet. Up to 10,000 feet the frequency of winds of this range is lowest in spring and highest in winter. Above 10,000 feet the speed of westerly winds increases much more rapidly with height than that of south-westerly or north-westerly winds. Winds from the south, south-west, north-west and north tend to become westerly with increasing height.

Of 327 sets of observations examined, only eight cases were found on which there was a definite reversal of wind. Six cases of these were of east or south-east wind currents at low levels above which were wind currents from different directions. The change in each case took place at a height of about 3,000 feet. The smallness of the number of cases of this kind observed may be somewhat misleading, as there is frequently a layer of cloud at the height at which a reversal

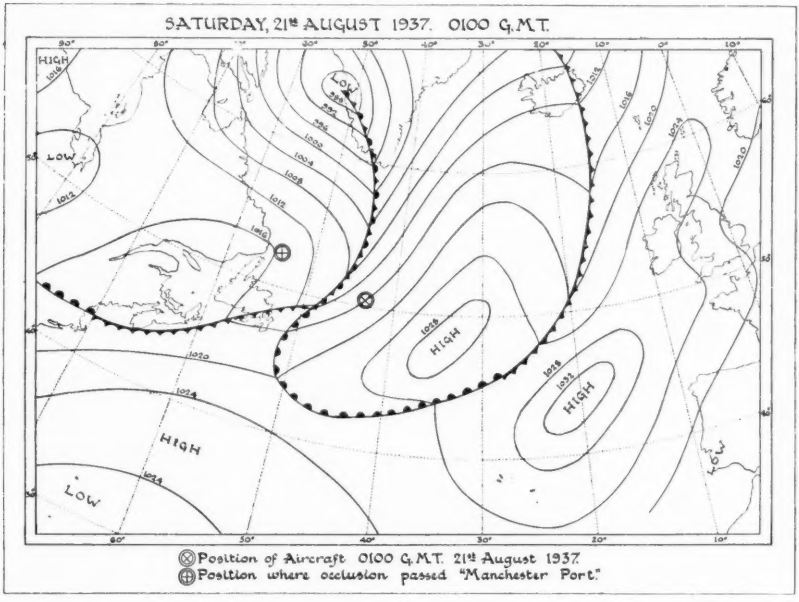

FIG. 12.

takes place; in such a case the pilot balloon could not have been followed after it had entered the cloud and no information about the wind at higher levels would have been obtained.

For the operation of a trans-Atlantic air service it is essential to supplement the regular observations of upper winds obtained from land stations from similar observations made over the sea. Series of such observations have been obtained in the past in the course of expeditions, which have provided material for investigation. For example, during 1937, a technical officer of the Meteorological Office was attached to the "Manchester Port," one of the ships of Manchester Liners, Ltd., operating between Manchester and Canada. During this period he completed eight round voyages in the course of which he made regular pilot balloon observations, in addition to obtaining further valuable information regarding Atlantic weather conditions. The German Meteorological

Service have equipped three ships for regular pilot balloon observations on each of the three routes to New York, the West Indies and South America. This arrangement ensures that at least one ship on each route is in a position to transmit upper wind observations from the ocean. To complete the network it is desirable that a similar arrangement should be brought into operation on the North Atlantic on a route as far north as possible.

UPPER AIR RESEARCH: THE "STATIONARY" SHIP.

Even if it were possible to arrange for a satisfactory network of pilot balloon observations over the North Atlantic, the information available for a complete day-to-day study of Atlantic weather conditions would still be incomplete. Synoptic meteorology is a three-dimensional problem and one of the most important series of observations is that of temperature and humidity at different heights. Hitherto these observations have been obtained in different countries from aeroplanes. For example, meteorological flights are maintained by the Royal Air Force at Mildenhall and Aldergrove for the sole purpose of making observations

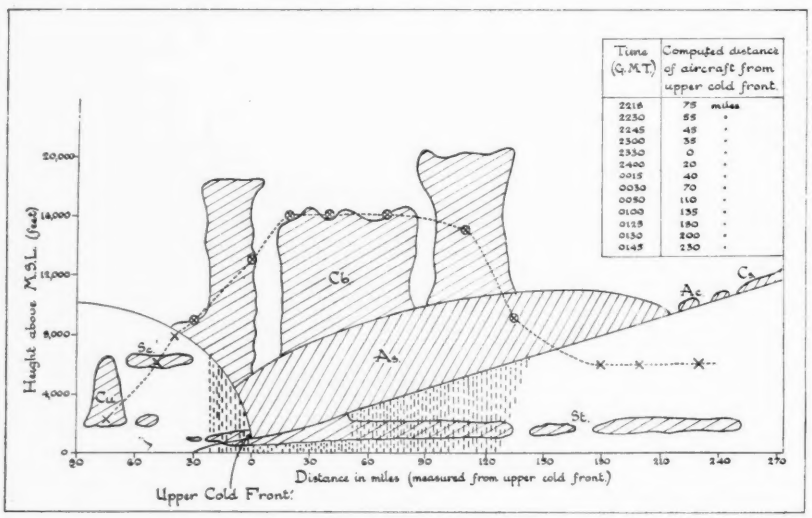

FIG. 13.

Vertical structure of occlusion, August 21, 1937.

twice daily, up to heights of 20,000 feet, for the benefit of the Meteorological Office. The development in recent years of the radio-meteorograph or radio-sonde now enables regular aerological information to be obtained in all conditions of weather at much less cost. The radio-sonde consists of a high frequency radio transmitter which is actuated by a barometer, thermometer and hygrometer of light weight but of high precision. The instrument is borne aloft on a balloon and transmits signals indicating the variations of pressure, temperature and humidity.

A complete analysis of the atmosphere in the vertical is necessary in order to identify different air masses and to trace lines of discontinuity. As an example of the value of this method of treatment of the problem Fig. 13 shows a vertical section of the atmosphere during the first part of the flight of "Caledonia" from Botwood to the Shannon on August 20/21, 1937. The relevant weather chart is reproduced in Fig. 12. This picture of a section of an atmospheric disturbance was

prepared by the meteorological staff at the Shannon after receiving the meteorological observations from the aircraft log. An occlusion from a depression centred over the west coast of Greenland extended southwards to approximately 50° N., 48° W., and from thence a cold front extended south-westwards and a warm front south-south-westwards. The air in the warm sector of this frontal system was of tropical origin and had reached Newfoundland from the Gulf of Mexico by way of the Eastern States and Nova Scotia.

The " Caledonia " left Botwood for Foynes at 21.30 G.M.T. on the 20th and therefore flew right across the system; comprehensive weather observations were recorded in the log. In addition the occlusion was passed by the s.s. " Manchester Port " (en route for Montreal) about 12 hours earlier than it was crossed by the " Caledonia," and observations were made by the meteorological officer before, during and after the passage of the occlusion. The logs of the " Caledonia " and the " Manchester Port," together with the appropriate synoptic charts, were used in building up a picture of the frontal structure in the horizontal and the vertical.

After leaving Botwood the aircraft was climbing in polar air, passing through the cold front surface at an altitude of just over 8,000 ft., shortly after which it was climbing in cloud with heavy rain (see Fig. 13). This was, doubtless, the convection cloud over the cold front surface, and the observations were sufficiently complete to enable the position of the upper cold front to be fixed to within a few miles. After flying in the tropical air for more than two hours the aircraft descended through the warm front surface. Using the upper cold front as origin, and taking into consideration the relative speed of aircraft and front, it was possible to draw a picture of the occlusion structure.

The outstanding feature of the occlusion structure was the marked instability experienced in the tropical air. At a height of 16,000 ft. the aircraft was flying through cloud tops that were undoubtedly those of cumulo-nimbus clouds which rose upwards from the warm front surface alto-stratus layer. About 100 miles in advance of the upper cold front the aircraft started to descend, and icing and heavy hail showers were experienced to the accompaniment of strong vertical currents; it would appear that instability was greater here than nearer to the upper cold front. Further descent brought the aircraft into clear air between the alto-stratus layer above and the typical prefrontal polar air stratus or strato-cumulus layer below. At this point it is relevant to record that the " Manchester Port," when passing through the occlusion, experienced almost continuous and predominantly heavy rain for a period indicating a rain belt some 110 miles in width in the vicinity of the front.

The main point of this example is that it reveals a structure of the atmosphere not frequently met with, viz., the existence of instability, as evidenced by large cumulo-nimbus clouds, over the alto-stratus layer of a warm front surface. Apart from the single observation of heavy rain by the observer on the " Manchester Port " (which was not received till some time later) there would have been no evidence for this structure apart from the experience of the " Caledonia." Hence the necessity for completing the network of observations over the ocean by the addition of pilot balloon and radio-sonde observations.

While it has been proved possible to make regular pilot balloon observations on a moving ship, it would be less practicable in the case of radio-sonde observations. The difficulty has been overcome on the southern North Atlantic route by the establishment, by the French Meteorological Service, of a " stationary " ship, the " Carimaré," about halfway between the Azores and Bermuda. Two voyages have been made, the first from 25th August to 4th November, 1937, the second from 4th April to the 4th July, 1938. The primary object of these voyages was to obtain aerological observations over the ocean and to act as an intermediate meteorological and radio base for trans-Atlantic flights. In addition to being fitted as a first-order meteorological station and, in addition, equipped for pilot balloon and radio-sonde work, the " Carimaré " had facilities for weather forecasting

and was also fitted with radio direction finding equipment. The collective weather reports from Europe and North America were intercepted regularly as well as reports received direct from a large number of ships, many of which would not have been able to communicate with shore stations. In this way very complete weather charts of the North Atlantic were prepared and the meteorological staff were in a position to issue valuable information for both air and marine services.

The value of such a ship on the direct North Atlantic route, about mid-way between Ireland and Newfoundland cannot be over-estimated. Much more complete information could be obtained than is possible with existing facilities. An additional direction finding station would also be of material assistance to trans-ocean navigation. If such a service were maintained continuously, two ships would be required and the cost would, of course, be considerable.

There is much which remains to be done in connection with the meteorology of the North Atlantic both from the investigational and operational aspects. The problem of flying at high altitudes makes it imperative that further information should be available regarding the wind structure at great heights while the question of the conditions which would give rise to ice accretion in winter, and the frequency of their occurrence, needs further investigation. Nevertheless the success which attended the first survey flights in 1937 and the progress which has since been made enable us to look forward with confidence to the day when a regular trans-Atlantic service is inaugurated.

Discussion.

The Chairman: He was grateful to Mr. Entwistle for his very clear lecture and the great amount of information he had given, and said that its value would be still further enhanced by criticism.

He invited Colonel FitzMaurice (who had flown the North Atlantic from east to west in 1928 with two companions and had landed on an island in the Gulf of St. Lawrence) to open the discussion.

Colonel FitzMaurice: The subject of weather conditions on the North Atlantic appealed to him strongly, for on the occasion referred to by the Chairman he had been particularly interested in the weather over the North Atlantic, when flying in a very frail and fragile aircraft.

In view of the interesting information given in the paper, which served to indicate the great progress which had been made in recent years in broadcasting weather forecasts, he quoted, for purposes of comparison with present-day reports, the weather forecast he had received prior to his North Atlantic flight in 1928, and recalled some of his experiences on that flight. He and his companions had started from Baldonnel, on the east coast of Ireland, at 5 o'clock one morning in April, 1928, and had landed eventually on Greenly Island, in the Straits of Belle Isle. A weather report had been provided by Mr. Entwistle at 5 o'clock of the afternoon preceding the flight, and that report was confirmed at midnight. The report was as follows:—

> "Wind to longitude 15 deg. west is mainly between south and east, averaging 15-20 miles per hour at the surface and 30-35 at an altitude of 2,000ft. West of longitude 30 deg., winds tend to decrease toward New York. All along the route the sky is three-fourths to fully overcast, with a cloud base mainly 1,000-2,000ft. above the surface of the sea. There probably will be a slight or moderate rain about longitude 20 deg. General visibility is 5-10 miles, apart from precipitation. There is no danger of fog, sleet or hail.
>
> "Barometric disturbances are such that an error in the altimeter will be in the favour of the 'Bremen's' pilots."

Having seen an example of the very perfect reports that were given to the pilots of the Empire flying boats on the occasions of the experimental flights across the

North Atlantic recently, said Colonel FitzMaurice, he could appreciate that terrific progress had been made to ease the difficulties of North Atlantic navigation.

Discussing the events of his Atlantic flight, he said that after leaving Baldonnel he had found the weather to be exactly as predicted, for a time. Off the Irish coast, he and his companions had seen a steamer, and by the column of smoke from its funnel they had observed that there was a slight southerly breeze. The weather was then perfect. About two hours after leaving the Irish coast they had run into a completely overcast sky, there was a reduction of temperature, a south-west wind increasing in strength, and quiet drizzling rain. A little later, the wind swung to the north-west and freshened; the conditions were thus a little different from those forecast in the report, but the varying winds experienced were more or less expected. About noon, the sun, which had seemed to lag behind them, reached the meridian slowly, and a long time seemed to elapse before it began to shine in their faces. It was noon by the sun, but the chronometer was already ahead by $1\frac{3}{4}$ hours. They estimated that by that time they had passed the 30th Meridian, and they had an approximate idea of the distance so far covered. They estimated that the ground speed was approximately 110 m.p.h.; they had covered about 950 miles, and had still another 1,250 miles to travel before reaching safety.

When the chronometer showed 4 p.m., the wind freshened further. They had flown most of the time at a height of about 50ft. off the surface of the water, as the German pilots did when crossing the South Atlantic, so that when they came to a head wind they could gain as much as possible. During the afternoon they used smoke bombs to give an idea of the wind direction and velocity. In the early afternoon the wind had swung back to the south-east, the velocity being from 15-20 m.p.h. They climbed to a height of about 2,000ft. to take advantage of that following wind, and during the late afternoon they experienced very bright weather, following winds and light clouds. By about 5.30 p.m., the wind had swung again to the north-west and had increased considerably in velocity. They descended to an altitude of about 50ft. again, and corrected course by ruddering 15° to the north.

On the evening before the departure they had watched the sunset from the highest piece of ground adjacent to the aerodrome at Baldonnel, at a height of about 600ft. above sea level. The sun had then disappeared at about 7.45 p.m., and at 9.30 p.m. there was complete darkness. On the following day, however, when over the Atlantic, the sun stood quite high in the sky when the chronometer had shown 7.20 p.m. From 7.40 p.m. onwards they began to count one degree for every four minutes that elapsed whilst they could see the sun. That would give an approximate final check up on their position for the further flight into the night. But it did not work out so well as was hoped. After $1\frac{1}{2}$ hours the glowing strip which the sun had thrown on the water suddenly disappeared, and was replaced by a dull whitish strip, which proved to be a wall of fog. Behind it there was almost a gigantic mountain of jet black clouds reaching up to about 20,000ft. It was impossible to fly over that cloud, for the machine was still carrying more than half its load of petrol. Had they endeavoured to climb over it the machine would probably have picked up ice, which would have resulted in a forced landing. It was decided, therefore, to fly through it. They entered the most foul weather, and were bounced about for quite a long time. However, the machine did not pick up ice. They remained in an area which gave about 2ft. above zero all the time, and finally got through after flying blind for about eight hours.

In those days the 24-hour weather forecasts were available, and they were more or less correct. But the journey from Ireland to Newfoundland occupied 24 hours in those days and aviators did not know what was coming up from the American coast. He agreed with Mr. Entwistle, therefore, that if there were available six reports daily from the American Continent, giving information concerning the weather coming from that Continent, they would be of very great advantage.

He agreed also as to the necessity for the establishment of the ship such as that between the Azores and Bermuda in order to give pilots an idea of the weather. He suggested that the ship should be fitted for balloon observation, and that there should be a seaplane which could be shot into the sky to take up the recording instruments. By such means they would be able to estimate much more closely than they could to-day conditions at higher levels—and aviators were more concerned with the conditions at higher levels than with the conditions at the surface. When such information was available the problem of flying across the North Atlantic would be reduced to very simple elements and they would all be able to spend week-ends in New York.

Captain WILCOCKSON (who piloted the Empire flying boats across the North Atlantic): He would first of all like to pay a tribute to Mr. Entwistle in respect of the work he had put into the organisation of the experimental flights over the North Atlantic. The flights were carried out with the assistance of all meteorological facilities. The great enemy of such flights in the ordinary way was the lack of meteorological information, but Mr. Entwistle's organisation had certainly overcome this difficulty. The first crossing was naturally rather worrying, as there was always doubt as to whether Newfoundland was really there. He was, of course, very happy to see it, even though he had been quite certain that it ought to be there.

On the second trip the weather was very bad; the aircraft was flying at a height of about 200ft., rain was falling and for seven hours he had not picked up a ship's bearing and he had not seen the sky. After about seven hours, however, he had passed over a ship named " The Maplewood " and he had circled round it and had asked the Captain for his position. The Captain had said that he would give it for what it was worth, but he had seen nothing for four days. Captain Wilcockson was fully in favour of the establishment of a ship in mid-Atlantic for meteorological observations, as he would at least be able to get a correct position when the aircraft passed over it.

There was a tendency at the present time among pilots in the profession to decry the fact that the qualification for the new licences involved more knowledge of meteorology. It should be borne in mind, however, that for pilots who were going to indulge in trans-ocean flying, meteorology was one of the most important things they could study.

Commenting upon the fact that on one occasion he had made a diversion from his course of about 400 miles to the south, and yet had completed the trip across the ocean in about 2½ hours less than the time which would have been taken on the trip if he had followed the direct route, he emphasised that the saving of 2½ hours flying time represented a very great economy on a modern four-engined aircraft, apart from the fact that the period of tension on the pilot's nerves was reduced by 2½ hours.

Perhaps the establishment of two ships on the Atlantic for meteorological observations might be regarded as somewhat luxurious, but if Mr. Entwistle could secure even one, he would confer an enormous benefit on all concerned with trans-Atlantic flying.

Colonel GOLD: He recalled that about 70 years had elapsed since the late Sir Francis Galton had suggested to the shipping community that they should construct charts—isodic charts—showing the ocean courses which would occupy the least amount of time when allowance was made for the effects of ocean currents and meteorological conditions upon the ships. That was a complicated question. The effect of wind on a ship was substantial and might have been well known at the time Sir Francis had made that proposal, because most of the ships at that time were sailing ships, but the effect had become of less significance and a little less certain as ships had changed over to steam. The effect of wind on an aeroplane, however, was simple and direct, so that it was a simpler problem to indicate to an aeroplane pilot the course which should be followed from point to point in order to complete the journey in the shortest time. But it was of no use trying to

deal with that matter on the basis of averages. In the case of a ship sailing in a trade wind, one might arrive at quite a good course on the basis of averages; but for aircraft, Mr. Entwistle had to deal with individual occasions, and, therefore, not only must he make complicated calculations, but he must make them quickly. His staff would not be able to occupy a week working out the course that a pilot should follow on an individual occasion. Although the effect of wind on aircraft made the problem for them simpler, yet in another direction the problem for aircraft was more complicated than that relating to ships, because whereas ships must remain on the surface of the water, the aeroplane had unlimited choice as to the level at which it should travel. Therefore, if the aeroplane pilot were to derive full advantage from information collected and analysed by the meteorologist, he must have information of conditions at different levels. He did not know how much progress had been made in dealing with the various levels from the point of view of economy of flight. It involved many factors in addition to the speed and direction of the wind at different levels. But a proper use of the meteorological information could save hours on a 20-hour flight.

Another aspect of the problem to which the paper had not referred was that of the comfort of flying. They did not want passengers crossing the Atlantic by air to be tossed about as they sometimes were in ships at sea; the pilot would wish to ensure for them the most comfortable crossing possible, by selecting levels comparatively free from turbulence. That was one of the reasons why Mr. Entwistle wanted to establish in the North Atlantic a ship similar to the "Carimaré," the observations from which would help to indicate not only the most economic course but also the most comfortable course to follow. He congratulated Mr. Entwistle upon a very comprehensive and lucid account of the meteorological problems of the North Atlantic.

Squadron Leader CUMMING: He was concerned mainly with the section of the Atlantic between Bermuda and the United States; but that particular section was of considerable interest to the meteorologist, and Mr. Entwistle would be the first to agree that a considerable amount of knowledge had been gained concerning the weather in that section, not only from the point of view of forecasting in the ordinary way, but also with regard to the vagaries of weather which could arise over comparatively short distances and over the open ocean, where one did not normally expect violent changes of weather. It seemed to him that an observation ship might also be established in that direction, because by means of such a ship it would be possible to follow more closely the actual changes of weather that occurred, after or during the formation of the North Atlantic depressions. On many occasions there had been forecasts of very fair weather between Bermuda and the United States, but, in fact, bad weather had occurred, due to the unexpected developments; although probably such developments did not occur to the same degree over the North Atlantic proper, there might be quite serious developments there, which would not be known to the forecaster if he were furnished only with information from casual shipping, and from stations in the United States and in Europe.

He was anxious to join in the tribute to Mr. Entwistle because the whole problem of meteorological organisation was immense, and the manner in which that problem had been tackled left nothing to be desired by the practical operator of an air-line. Obviously we had a long way to go yet; but the method by which the problem was tackled was important and, in respect of that method only, unstinted praise was due to Mr. Entwistle and his organisation.

Captain BENNETT: His experience of the results of Mr. Entwistle's organisation had been really excellent. The advantages to be derived from the establishment of an observation ship in mid-Atlantic were tremendous, not only from the meteorological point of view but also that of navigation, and pilots would very much appreciate such a service. The expense of establishing and maintaining such a ship, of course, was not a matter for discussion by the Royal Aeronautical Society. At the same time, he expressed the opinion that more investigations by means

of aircraft would be most valuable. Information concerning the upper air temperatures and the winds would best be obtained by means of aircraft, and as it is not practicable to send up aircraft from a ship in mid-ocean at frequent intervals, the next best thing to do would be to send the aircraft across the ocean.

Mr. M. LANGLEY (*Member*) : He asked Mr. Entwistle to expand his explanation of the increased speed attained by the German machines as the result of flying near the surface of the water. He recalled an *ad hoc* experiment he had made in his very early childhood, from which he had discovered that anything that went up must come down again. It was reasonable to develop that argument, he said, and to say that if a current of air were rising on one side of a wave, one would expect it to go down somewhere on the other side. If, therefore, an aeroplane flying close to the surface of the water received an uplift on one side of a wave, one would expect a " negative lift " on the other side. He suspected that the German pilots had experienced one of two things—either that they had given the first and only example known of the practical application of the Katzmayr effect, about which so much had been written in text books, or there had been a reduction of induced drag due to the ground effect close to the surface.

(*Communicated*: A rough calculation, made after the discussion, showed that an increase in speed of 6 m.p.h., due to reduction of induced drag, might be expected with an aeroplane like the Hamburg H.A. 139 Catapult Seaplane, when cruising at about 150 m.p.h., with a wing loading of 25-30 lb. per sq. ft. at a height of 20-30ft. above the sea).

A factor which affected directly the design of aircraft for North Atlantic work was the allowance to be made for head winds. The charts produced by Mr. Entwistle had shown the number of days on which a 40 m.p.h. head wind might be expected over the North Atlantic, and in the designs of long-range aircraft allowance had to be made for that head wind. One could design an aeroplane to fly direct from Southampton to New York at over 200 m.p.h., using a cruising power of 3,200 b.h.p. and having an initial wing loading of 45 lb. per sq. ft. It would carry no pay load if an allowance in fuel for a 40 m.p.h. head wind had to be made, but this allowance would be equivalent to a pay load of about two tons.

The " headwind allowance," therefore, makes the difference between a revenue and a dead loss, but at present they dare not take the risk of flying without it.

A story had been circulating for some months to the effect that it was impossible to operate flying boats on the North Atlantic route because, for six months of the year, there was ice on the American coast as far south as Baltimore. He was somewhat doubtful of that story, and had discussed it with a Major in the Canadian army recently, who said it was humbug, and added that for two years he had been stationed at Halifax, Nova Scotia, and although throughout the whole of that period he had made a daily trip across Halifax harbour, he had never seen ice there. Further, Mr. Langley said he had also been in touch with Mr. J. H. Parkin, of the Canadian Government National Research Council, and had asked him about conditions on the Atlantic seaboard. His reply was that he had obtained reports from Halifax, from St. John (New Brunswick) and St. John's (Newfoundland). The reports stated that, although ice might form under certain conditions around parts of Halifax, it was quickly broken up by winds, and there were no records of Halifax harbour being frozen over since the winter of 1821.

At St. John (New Brunswick) there was no floating ice in the harbour. Ice coming down the river is practically dissipated by the time it goes over the Reversing Falls and there are no blocks of ice which would damage flying boats. On the other hand in Newfoundland, from Cape Ray north through the Straits and thence south to Cape Race, the coast is closed to shipping on account of ice from, generally, late December until 1st May following, and from Cape Race west to Cap Ray, the coast is generally clear except in early spring when drift ice from the Gulf may be encountered, and that confirmed the information given by Mr. Entwistle. Therefore, in order to land at St. John's (Newfoundland), it would be necessary to use aeroplanes instead of flying boats during the winter

months; but the flying boats would come into their own again if their range could be extended to Halifax or to St. John (New Brunswick). He asked if Mr. Entwistle's experience would bear that out. It was a matter of very great importance to the future development of flying boats by this country.

Captain J. LAURENCE PRITCHARD (Secretary and Editor, Royal Aeronautical Society): With reference to Mr. Langley's statement of the allowance which had to be made in the design of North Atlantic flying boats for the 40 m.p.h. head wind sometimes encountered, he thought that if, as stated in the paper, such a head wind occurred only during 1.2 per cent. of the year, the best policy would be to find out from Mr. Entwistle the occasions on which that head wind would occur and to avoid flying on those occasions. An alternative was to fly at great heights—he did not mean heights such as 30,000ft., but heights of 17,000ft.-20,000ft. In that connection he drew attention to the American Explorer II stratosphere flight which had produced first class meteorological records. Those records, which were among the best he had ever read, and indeed were among the very few that he had been able to understand, had shown that with increasing height the wind changed round. That was confirmed by one or two other records. It seemed to him, therefore, that one should be able to decide the heights at which aircraft could cross the Atlantic with the aid of following winds or, at worst, in conditions of dead calm, and to avoid head winds. He asked whether co-ordinated attempts had been made to study the upper atmosphere over the Atlantic. He knew, of course, that kite balloons and the radio-sonde had been used in order to obtain information, but one of the difficulties was that the information obtained was not co-ordinated. He would like to see the information condensed and presented in such a form that ordinary people could understand it.

He thought that the speakers in the discussion had not used, sufficiently, the opportunity to question Mr. Entwistle and to gain from him information additional to that contained in his very excellent paper. He thought, too, that the really important consideration in connection with flights from this country to America was the condition of the weather at New York or at any other city at the time of landing. In a modern machine one could fly straight through almost anything, and if the machine of the present day could do that, then the machine of ten years hence would not need to bother about flying weather. In his view, successful landing would not depend upon knowledge of meteorological conditions, but upon directional wireless, and so on. One might almost say that the sooner weather charts were abolished altogether, the better.

THE CHAIRMAN (Mr. Griffith Brewer): He asked for an opinion as to whether Andree and his companions, who had left Spitzbergen 40 years ago on a balloon flight, would have been able to get to the North Pole or would have been persuaded to wait for a more favourable opportunity had they been able to call for the help of the Meteorological Office. After leaving Spitzbergen they had vanished into the blue, and from the records which were found afterwards it seemed that they had drifted only 500 miles north of Spitzbergen and eventually trekked back over the ice to White Island on which they had died.

Having crossed the Atlantic by steamship on more than 60 occasions, continued the Chairman, he had noted that when the voyage had started with an east wind, that wind had never persisted right across the Atlantic. Only on one occasion last January, on a voyage to the West Indies and Panama, had the east or north-east wind persisted throughout the trip. There were very few exceptions to the rule that a ship could not carry the east wind all the way to America, and he wondered if that rule applied also to the aeroplane with its much greater speed.

REPLY TO THE DISCUSSION.

In reply to the Chairman: On the average there was one day in ten years on which an east wind extended right across the Atlantic. The number of occasions increased gradually as the distance was reduced to three-quarters, a half, and one-

quarter of the total distance, but east winds were relatively infrequent. As the Tables showed, there were certain periods of the year in which there were strong easterly winds, those periods occurring particularly in winter, but the periods were relatively short.

He had been wanting to meet Colonel FitzMaurice, he said, for many years in order to explain to him certain circumstances which had occurred on the occasion of his historic North Atlantic flight. In those days, of course, they had not the advantage of the organisation existing at the present time and they were not able to discuss the weather chart and to talk over the situation from every point of view. All the talking on that occasion was done over a rather bad telephone wire between the Air Ministry and Dublin. The forecast that was given was based on a misapprehension, or, perhaps, it would be more true to say that it was accepted under a misapprehension. Under the conditions existing at that time one could not have attempted, normally, an accurate forecast over a period of more than 24 hours ahead. He remembered having said definitely then that there would be no fog over Newfoundland for 24 hours. He had been very disappointed, therefore, when he had heard that the aeroplane had not taken off during the night, as he had been led to expect, but that it had left on the following morning, because he had realised that it would not arrive over Newfoundland until after the expiry of the 24-hour period covered by the forecast when the fog had actually occurred there.

Discussing the references to the possible use of seaplanes for obtaining information regarding upper air conditions over the Atlantic, he said that perhaps he had not made himself clear concerning the radio-sonde. Although this instrument had been under development for a number of years, it had not quite reached the stage of perfection at which they felt they were justified in using it for regular observations in this country. However, he believed that that stage would be reached very soon. In that connection he read an extract from a resolution passed at a meeting of the International Commission for Synoptic Weather Information (of which Colonel Gold was Chairman) at Salzburg in September, 1938, as follows:—

> "The development of the radio-sonde has placed at the service of synoptic meteorology a new and powerful instrument for the exploration of the upper atmosphere in all conditions of weather. Full use of the observations which the instrument provides requires the co-operation of all meteorological services to establish a network of such stations. Only by the provision of a network of stations can the construction of the necessary upper air and particularly stratospheric charts be prepared. The Committee considers that a network of about 50 stations is necessary for Europe and a corresponding density is desirable for other parts of the temperate zones. A network of stations is equally necessary in the tropics and polar regions. The Committee recognises that the maintenance of these stations and the provision of the personnel required to operate them will involve considerable expense; but it is convinced that further advance in forecasting and the solution of the problems arising from the extension of flying at great distances and heights depends on the establishment of an organised system of radio-sonde observations."

The point with regard to the radio-sonde was that it gave information of conditions at far greater heights than could be reached by an aeroplane carrying instruments; its range extended right into the stratosphere in all weather conditions. The meteorological flights of the R.A.F. in this country frequently operated in very bad weather conditions; twice a day they ascended to a height of 20,000 or 25,000ft. But the radio-sonde would give information of equal value and accuracy to that obtained by the meteorological flights, extending to very great heights; therefore, he did not visualise the use of a seaplane from the stationary ship, but rather the use of a radio-sonde, which could explore the upper atmosphere as frequently as was required.

Dealing with Mr. Langley's reference to the reported gain of speed of aircraft when flying low over the waves, he suggested that that increase was due to a combination of three factors. In the first place, the wind was less near the surface than at higher altitudes; secondly, there was the "ground" effect to which Mr. Langley had referred; and thirdly, he pointed out that while air which went up had to come down, it did not always go up and come down in the same way. In the case of the wind blowing over the waves, the upward current extended over the crest of the wave, the downward current occurring at a lower level on the lee side of the wave. An aircraft flying a few feet above the crests of the waves would thus experience a series of upward impulses. That was a partial explanation of the increase of lift obtained off the crest of a wave.

There were two factors to be considered in connection with the distribution of ice. First, there was the ice which formed *in situ* owing to freezing conditions prevailing; and secondly, there was the drifting of the polar ice to the south in the late winter and early spring. He believed that the difficulty referred to on the American coast south of Newfoundland was not due to freezing, but to drifting ice. That ice was liable to drift as far south as New York, and even beyond. But it did not hinder shipping in winter, for at that season, when the St. Lawrence was frozen over, Halifax was the terminus of the North Atlantic route. A flying boat squadron of the Royal Canadian Air Force was stationed at Halifax. A few years ago, during the summer months, a detachment was stationed at Sydney, Cape Breton Island, but that detachment was always sent to Halifax during the winter, largely, he believed, because of the ice problem. Provided that information were available concerning ice which was liable to drift into the harbours, he did not see any reason why flying boats should not be used south of Newfoundland; but at Newfoundland it was out of the question in winter, because of the freezing of the harbours for the period of six months in the year.

The weather between Bermuda and New York, of course, was very different from that on the North Atlantic route. On the whole, perhaps, there was less experience and data available concerning the conditions between Bermuda and New York. He suggested that the difficulties which Squadron Leader Cumming had mentioned would disappear in the course of time, as more experience was gained.

The remarks of Captain Pritchard were very refreshing; his allusion to the abolition of weather charts and to air pilots flying without the help of meteorology, recalled an occasion, not many years ago, on which he (the lecturer) had opened a discussion, arranged by the Guild of Air Pilots, on the subject "Can the Air Pilot dispense with Meteorology?" Everybody present on that occasion had expected him to justify meteorology; but in order to draw discussion, he had taken the opposite point of view and had suggested that, owing to the development of aviation and navigational aids the day was fast approaching when the pilot could dispense with an organised meteorological service, even if he could never dispense with meteorology. A storm of protest had arisen, and it was claimed by speakers, who were all practical and experienced pilots, that aviation would never be able to do without a meteorological service. Experience had certainly shown that while, as aviation developed, the method of application of meteorological information also underwent development, meteorology was as essential to aviation to-day as it was 20 years ago.

Colonel Gold had pointed out that the problem of the effect of wind on an aircraft could not be dealt with solely on the basis of averages. But the tables shown during the lecture provided information which was essential both to designers of aircraft and to those responsible for aircraft operation. In the same way, further information is necessary regarding the frequency of winds from different directions at great heights. Captain Pritchard had referred to the difficulty of getting information co-ordinated and presented in a form in which it could be understood. A great deal of data was available in the Meteorological Office and it was the aim of that department in regard to aviation developments, to look

ahead as far as possible and provide answers to questions which were likely to be formulated. But it was clearly the duty of those concerned with the development of aviation to state their problems so that additional data could be obtained, if necessary, and the answers to those problems provided. This applied very largely to the question of conditions at great heights, about which a certain amount of information was already available.

Replying to the Chairman's question concerning Andree's balloon flight from Spitzbergen, Mr. Entwistle said he had no doubt that, had adequate meteorological information been available at the time, the results of the flight would have been different. The same remark applied, perhaps, to some of the early Atlantic flights, which were undertaken with considerable zeal and enthusiasm, but in certain cases without proper regard even to the meteorological information which was available.

On the motion of the Chairman, a hearty vote of thanks was accorded Mr. Entwistle for his paper.

ABSTRACTS FROM THE SCIENTIFIC AND TECHNICAL PRESS.

Issued by the
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(Prepared by R.T.P.)

No. 63. JANUARY, 1939.

The Present State of Coastal Defence. (C. Rehder, W.T.M., Vol. 42, No. 8, August, 1938, pp. 356-365. Translation No. 788.) (63/1 Germany.)

In the future as in the past, properly designed coastal defences will be able to hold their own against any attack by ships. Modern defences will differ from previous installations by a much greater depth, with efficient protection on the land side.

All the heavy guns are mounted in gas-proof turrets and great care must be given to the equipment of the signals branch (warning of attack both from the sea or air). A coastal defence system should be able to hold its own without support from the home fleet. An adequate supply of small surface vessels must, however, be provided for scouting and mine sweeping. Reconnaissance aircraft must also be provided so as to reduce the possibility of surprise by an enemy aircraft attack coming from the sea. In a future war it will not be possible to build new coastal defences after hostilities have started, modern air raids rendering all work of this type impossible. It is, therefore, essential that available coastal defensive systems should be designed with an eye as to future requirements.

Success is only possible if there is complete and harmonious co-operation between all three services, fleet, air and army.

Training A.A. Searchlight Spotters. (L. E. C. M. Perowne, Coast Artillery Journal, No. 6, Nov.-Dec., 1938, pp. 430-41.) (63/2 U.S.A.)

Unlike the training of lorry-drivers and searchlight operators, we are faced in the training of spotters and listeners with making men proficient in a subject which has no counterpart in civil life. We have here the problem of developing the senses, but, whereas the sound locator provides in itself a ready means of demonstration, checking progress and registering the results of the listeners' work, the functions of the spotter furnish us at present with no such opportunities. Telescopic vision, moreover, is an art practised by few among those from which our potential spotters are drawn.

One of the principal objects of the system of training outlined above is, therefore, to furnish a scientific framework upon which to build, and to provide a basis for a series of tests to which both instructor and pupil can relate their progress.

Target Aircraft for A.A. Artillery Training. (S. L. McCroskey, Coast Artillery Journal, No. 6, Nov.-Dec., 1938, pp. 479-81.) (63/3 U.S.A.)

The general characteristics of the Denny targets are as follows:—

Ceiling: 7,000-8,000ft.
Maximum speed: 75 miles per hour (approximately).
Controls: Radio and automatic.
Wing span: 12ft.
Length of fuselage: About 8ft.
Parachute equipped, opening automatically to assist in landing without damage.
Fuel capacity: 30 minutes of flight.
Launching: Simple catapult.

These little targets do not have the characteristics required for anti-aircraft gun training, but they represent a step in the right direction. They may fill the bill for machine gun target use and also for the use of gun batteries. Many organisations, such as ROTC units, have scant opportunity to practise trackings because of lack of aeroplanes. If the Denny target will operate dependably, it may well meet the need in these cases.

In the meantime, studies looking toward the production of a target of greater capabilities continue. Such a target should not cost more than $1,500 in quantities. A list of desirable qualities is given by the author.

A Plotting Board for A.A. Target Practice. (H. W. Conklin, Coast Artillery Journal, No. 6, Nov.-Dec., 1938, pp. 482-3.) (63/4 U.S.A.)

In the analysis of an anti-aircraft target practice it is necessary to determine the speed of the target. The only method that can determine this speed accurately is a plot of the horizontal projection of the course. Since this plot has to be made and is made from the data furnished by the camera stations accurately located at the ends of a surveyed baseline, there is no reason why the horizontal ranges from the base end stations should not be read directly from this plot.

Most anti-aircraft record sections have improvised boards upon which to do this plotting, but in many cases such boards have been locally and crudely made, and have been constructed so as to be of use for one particular baseline only.

To overcome the difficulty of using several boards, and to provide one universal plotting board suitable for a baseline of any length and azimuth applicable to anti-aircraft firings was the object of the design of the board described herein.

In addition to the horizontal plot, this board, by the addition of a grid chart, will also serve as a slant range board solving the elements of the right triangle in the vertical plane, *i.e.*, slant ranges and altitudes.

Comparison of French and German Air Power. (H. Bouché, Int. Avia., No. 602, 17/12/38, pp. 1-3.) (63/5 France.)

According to the author, the following table gives a comparison between French and German air power:

	Front Line Strength. (Aircraft).	Front Reserves. %	Monthly Production. End of 1938. Aircraft.	Engine.	Labour. Force.	Weekly Working Hours.
Germany	3,000	60-70	400	1,000	120,000	6,960,000
France	1,400	20	70	200	48,000	2,160,000

From this it can be deduced that:

(1) The French front line strength is less than half the German.
(2) The German front reserves amount to over six times the French reserve.
(3) The time taken by Germany to pass a type from design to production stage is less than half the time taken by France.
(4) Taking the whole of 1938, the French production of aircraft and engines amounted to less than one-fifth of the German production.

The Objectives of Independent Air Attack. (G. Rohrig, Verkehrsrechtliche Schriften No. 6, Ost Europa Verleg, 1938.) (63/6 Germany.)

In a modern war the distinction between combatants and non-combatants has largely disappeared and hence the scope of the attack and the number of objectives have increased enormously.

The author defines the legal aspects of aerial warfare and the various attempts to arrive at international agreement at the Hague and Geneva are reviewed.

Unfortunately all these attempts have failed, so far, and even hospitals and works of art are not immune from air attack since illumination at night would not be practicable and other buildings forming more or less legitimate targets are generally sufficiently near to render " mistakes " possible. The only hope is a fresh world conference now that the consequences of indescriminate air attack are being more fully realised.

According to the author, Germany is ready to sign a pact with the Western Nations restricting the use of aircraft and preventing sudden attacks.

The book is well documented and contains extensive quotations from English, American and French authors.

Aerial Combat. (A. Surikoff and W. Nikolsky, Na Straje, 20/7/38, Luftwehr, Vol. 5, No. 11, Nov., 1938, pp. 447-450.) (63/7 U.S.S.R.)

Whenever possible, the attack should come as a surprise to the enemy. In case of equal training and material, victory comes to the fighter displaying the greater aggressive spirit. Any slackening of the attack immediately stimulates the enemy and may prove fatal. On account of the high airspeeds, the time of attack is relatively short (5-10 seconds). The advantage of the fighter over the bomber as regards speed has also been very much reduced and whilst three to four attacks could be carried out previously in quick succession on a bomber formation it may now take the fighters 15 minutes to catch up the bombers for a second attack.

The various manœuvres for breaking off the fight have to be carefully studied since during these moments the danger of assuming an unfavourable position is very great.

Experience in Spain has shown that the pilot who turned away first was frequently shot down. For this reason it appears useful to utilise two types of fighters simultaneously. Very high speed machines for breaking up the enemy formation and lower speed machines of great manœuvrability for the subsequent " dog fight."

Protection of Buildings Against Incendiary Thermite and Electron Thermite Bombs. (F. J. Hombracht, De Ing. (Bouw en Waterbouwkunde), Vol. 53, 16/9/38, pp. 161-3. Eng. Absts., Vol. I, No. 11 (Sect. I), Nov., 1938, pp. 123-4.) (63/8 Holland.)

The author states that bombs used during recent wars have been filled with a mixture of powdered aluminium and ferric oxide. This ignites easily and produces in its combustion temperatures of 2,000-3,000°C. during three to four minutes, whilst if encased in " elektron " shells, made of a combustible alloy of magnesium and aluminium the combustion period is extended to 10-12 minutes. It is difficult to find building materials both cheap enough to be used extensively, and capable of resisting such high temperatures. The author proposes the use of cover-plates made of clay or loam containing straw, cut to lengths ranging from 20 mm. to 50 mm. and mixed in the following volumetric proportions: Three parts chopped straw; one part clay or loam; ½ part ciment fondu; ½ part milk of lime diluted to 15° Beaume; the moist mixture to weigh 1.1-1.2 kg. per litre. Such plates become firm and are very porous. They are bedded on paper or board rendered waterproof by being soaked in oil. A thickness of about 25 mm. is suitable for vertical attic walls, and 35 mm. for floors. Plates of this type have been tested by dropping on them ordinary incendiary bombs weighing 3 kg.

(6.6lb.) and " elektron-covered " bombs weighing 1 kg. (2.2lb.) from a height of 35 m. (82ft.). It was found that the burning bomb forms a thick ash on the surface of the cover-plate, and that the moisture between the surface and the oiled paper forms a cushion of air or steam which prevents the heat from penetrating through the plate. Very little damage was caused to the plates. Tests are to be made with heavier " elektron-covered " bombs. The author states that the penetration of weak attic floors can be prevented by covering them with a thin layer of concrete reinforced with wire-gauze.

Theoretical Stability and Control Characteristics of Wings with Various Amounts of Taper and Twist. (H. A. Pearson and R. T. Jones, N.A.C.A. Report No. 635, 1938.) (63/9 U.S.A.)

Stability derivatives have been computed for twisted wings of different plan forms that include variations in both the wing taper and the aspect ratio. Taper ratios of 1.0, 0.50 and 0.25 are considered for each of three aspect ratios: 6, 10, and 16. The specific derivatives for which results are given are the rolling-moment and the yawing-moment derivatives with respect to (*a*) rolling velocity (*b*) yawing velocity, and (*c*) angle of sideslip. These results are given in such a form that the effect of any initial symmetrical wing twist (such as may be produced by flaps) on the derivatives may easily be taken into account.

In addition to the stability derivatives, results are included for determining the theoretical rolling moment due to aileron deflection and a series of influence lines is given by which the loading across the span may be determined for any angle-of-attack distribution that may occur on the wing plan forms considered. The report also includes incidental references to the application of the results.

The Moment of the Fluid Pressure Acting on a Flat Plate in a Stream Between Two Parallel Walls and Some Allied Problems. (S. Tomotika, Aer. Res. Inst., Tokio, No. 170, Oct., 1938, pp. 475-551.) (63/10 Japan.)

In the present paper, the problem of the moment of the fluid pressure acting on a flat plate in a stream between parallel rigid walls is solved in an exact and general form, by using suitable conformal transformations, under the assumption that there is circulation round the plate. After detailed numerical calculations for the particular case when the mid-point of the plate is midway between the walls, the interference effect of the channel walls upon the moment on the plate is discussed and also an investigation is made on the manner in which the centre of pressure of the plate is affected by the presence of the channel walls. It is found that the moment of the plate always increases due to the influence of the walls and that when the angle of attack lies within the practically important range, the centre of pressure of the plate moves towards its mid-point as the width of the channel decreases. An expansion for the moment is also obtained for the particular case concerned.

Next, the values of the moment for the plate in the case of flow with circulation round the plate are compared with those of the moment for the case of flow with no circulation. It is found that the moment is slightly increased due to the presence of the circulating flow.

By removing either of the upper and lower boundary walls of the channel to infinity, we obtain two semi-infinite streams past a flat plate bounded respectively by a lower or upper wall. These limiting cases lead to results in agreement with previous expressions obtained by the author.

Pressure Loss in Flowing Gases. (R. Stroehlen, Archiv Warmewirtschaft, Vol. 19, Aug., 1938, pp. 209-13. Eng. Absts., Vol. 1, No. 11 (Sect. 2), Nov., 1938, p. 158.) (63/11 Germany.)

The author asserts that the usual method of ascertaining the pressure loss due to heat-interchange in flowing gases, on the basis of the equation for isothermal flow, leads to incorrect results. He demonstrates that the interrelation between

interchange of heat, pipe friction, and the resulting pressure drop can be deduced from the basic energy equation, and that close agreement between calculated and measured results can be obtained. It has been found, with the formulæ hitherto used, that in actual practice, in the case of the higher speeds of flow, the measured resistances were lower than would have been expected by the application of these formulæ. This discrepancy cannot be accounted for by the influence of the pipe diameter, but is more likely to be due to the altered flow conditions caused by the interchange of heat. The resistance to the flow is primarily influenced by the change of temperature in the direction of flow. The author presents an analysis based upon certain assumptions, and works a numerical example.

The Accurate Measurement of Static and Dynamic Pressure. (G. Kiel, L.F.F., Vol. 15, No. 12, 10/12/38, pp. 583-597.) (63/12 Germany.)

In the case of a biplane, it is relatively easy to find a region between the two planes in which the air speed corresponds with that of the undisturbed flow for the complete range of practical angles of incidence.

In the case of a monoplane, however, an accurate measurement of static and dynamic pressure would entail mounting the instrument at a considerable distance from the wing. Such an installation is clumsy, fragile and affects the drag of the complete aircraft. As an alternative, the author investigated the fitting of a small subsidiary wing above the main monoplane wing and mounting the static and dynamic pressure tubes in close proximity to the underside of the subsidiary wing. This scheme, although giving satisfactory results, is still clumsy and was finally abandoned for a novel method in which two pressure recording tubes are employed mounted respectively above and below the main wing. In this arrangement the static pressure recorders are connected together and by proper dimensioning of the pipe, the correct (undisturbed) static pressure can be tapped off at some intermediate point, whilst the total pressure can be read on either instrument. Experiments show that the new method is accurate over the full range of incidence, including flap operation and will be specially useful for determining altitude during blind landings.

The Aerodynamic Characteristics of Four Full-Scale Propellers Having Different Plan Forms. (E. P. Hartman and D. Biermann, N.A.C.A. Report No. 643, 1938.) (63/13 U.S.A.)

Tests were made of four propellers, with diameters of 10ft., having different blade plan forms. One propeller (Navy design No. 5868-R6) was of the usual present-day type and was used as a basis of comparison for the other three, which had unusual plan forms distinguished by the inward (toward the hub) location of the sections having the greatest blade width.

It was found that propellers with points of maximum blade width occurring closer to the hub than on the present-day type of blade had higher peak efficiencies but lower take-off efficiencies. This result was found true for a " clean " liquid-cooled engine installation. It appears that some modification could be made to present plan forms which would produce propellers having more satisfactory aerodynamic qualities.

The propellers with the inward location of the points of maximum blade width had lower thrust and power coefficients and stalled earlier than the present-day type.

Tests of a Contra-Propeller for Aircraft. (W. M. Benson, N.A.C.A. Tech. Note No. 677, November, 1938.) (63/14 U.S.A.)

Tests of an eight-blade contra-propeller of 32-in. diameter in combination with a four-blade, 36-in. diameter adjustable pitch, metal propeller at pitch settings of 15°, 25°, 35°, and 45° at 0.75 R were made in the wind tunnel at Stanford University.

The tests showed a significant increase in effective thrust of the combination over that of the propeller alone for values of V/nD somewhat below those for maximum efficiency and without a corresponding increase of power absorbed. From $\frac{1}{2}$ per cent. to $2\frac{1}{2}$ per cent. in propulsive efficiency was thus gained in this range. In all but one case, however, the peak propulsive efficiency of the combination was found to be from 1 to 2 per cent. less than that of the propeller alone.

Counter torque on the contra-propeller amounted to about 50 per cent. of the propeller torque.

Possibilities of the Jump-Off Autogyro. (R. H. Prewitt, J. Aer. Sci., Vol. 6, No. 1, Nov., 1938, pp. 10-14.) (63/15 U.S.A.)

(1) It appears that all-purpose autogyros can be built to " jump-off " up to 100ft. and that for special purposes, autogyros can be made to " jump-off " 200ft. In the former case, the gross weight of the ships will be increased less than 5 per cent. to account for the increase in blade weight and extra mechanism involved and in the latter case, the gross weight will be increased less than 15 per cent. for the same items. It is believed that the accelerations involved in the above predictions will not be excessive.

(2) The available kinetic energy in the rotor system for " jump-off " is directly proportional to the weight of the blades and to the square of the rotational speed of the rotor. Thus, with a given autogyro having the weight of the blades fixed, the height of " jump-off " is dependent upon the horsepower available for accelerating the rotor. This, in turn, is dependent upon the pitch setting of the propeller which, for relatively high jumps, would have to be of controllable type to provide adequate power for the rotor and yet hold down the engine r.p.m. at top speed.

Desirable Qualities of Transport Aeroplanes from the Pilot's Point of View. (B. O. Howard, J. Aer. Sci., Vol. 6, No. 1, Nov., 1938, pp. 15-19.) (63/16 U.S.A.)

The pilots have unqualified respect and admiration for the vision and ingenuity displayed by the designer in the development of the highly efficient present-day transport. They have conscientiously tried to improve their knowledge and ability to the end that the greatest operating efficiency could be derived from the equipment. However, the time is rapidly approaching when the " least capable " pilot will have reached the saturation point and a halt in the ever-increasing " pilot skill required " will be necessary.

For this reason the author is of the opinion that closer co-operation between pilot and designer is called for.

Static Longitudinal Stability and Longitudinal Control of Autogyro Rotors. (M. Schrenk, L.F.F., Vol. 15, No. 6, 6/6/38, pp. 283-9. Available as Translation T.M. 879.) (63/17 Germany.)

The present report discusses three different systems of elevator control and their effects on the stability and manœuvrability of autogyros: (*a*) ailerons and elevators (standard); (*b*) blade control (la Cierva); (*c*) gravity control (new).

The control sensitivity $\frac{dv}{d\beta}$, which is dependent to a great degree on the speed in system (*a*), becomes substantially more uniform in system (*b*), and practically constant through the whole range from zero to maximum speed in system (*c*). At the same time, the highest restoring moments attainable at pull-up become consistently smaller. The important characteristics of blade control and gravity control are:—

(1) Flattening out from a high-speed dive is smoother and with little stress;
(2) The aeroplane can be landed with very small control deflections;
(3) Steering is not too sensitive at high speeds;
(4) The maximum permissible speed can be easily and safely limited by control movements, a fact which constitutes a special safeguard for an autogyro rotor having a prescribed maximum co-efficient of advance.

The control force balance can be readily achieved by proper design of the rotor head with its suspension. The control forces (to be kept moderate) with blade control and gravity control also change linearly with the speed. The shifting of the equilibrium condition or balance of centre of gravity displacements, attainable by suitable structural design of the rotor head assembly, affects neither stability nor control force variation.

The Argus Variable Pitch Propeller. (O. Ursinus, Flugsport, Vol. 30, No. 25, 7/12/38, pp. 671-2.) (63/18 Germany.)

This propeller was exhibited at the 1938 Paris Salon and is of the constant speed type, the necessary adjustments being carried out automatically by means of a small subsidiary propeller placed in front of the hub of the main propeller and rotating in the opposite direction This propeller drives continuously on epicyclic gear housed inside the hub. The lateral wheels of this gear are in mesh with two spur wheels which thus rotate in opposite directions. The spur wheels embrace a control shaft placed at right angles to the main propeller axis. This shaft is under the combined action of centrifugal force and a control spring and will engage with the left or right hand spur wheel depending on the speed of rotation of the hub as a whole. A left or right hand engagement works the blades of the main propeller and thus alters its pitch so as to maintain constant speed. The control spring is adjustable by the pilot so as to give two different constant speed settings. By means of a special control lever the spring can be put out of action and zero blade incidence obtained.

It is stated that the propeller is intended for engines up to 450 h.p. No weights are given.

Glassy Landings. (Sci. Am., Vol. 160, No. 1, Jan., 1939, pp. 32.) (63/19 U.S.A.)

Judging height accurately when alighting on perfectly calm water is practically impossible. Within the last year, about 50 pilots and passengers have lost their lives in various parts of the world because of "glassy landings." Under glassy conditions, the pilot should not guess at height and follow the conventional manœuvre of gliding down and then flattening out a few feet from the surface. He may flatten out too late, and nose into the water with possibly disastrous consequences. What he should carry out is a "power stall." At about 50ft. from the surface of the water, he should open up the throttle of the engine a trifle, and pull the nose slightly above the horizon. The plane will then lose altitude slowly in an almost stalled attitude. The subsequent contact with the water will be harmless, although to land in a power stall on the much harder ground might not be so judicious.

Hydrodynamic and Aerodynamic Tests of Four Models of Outboard Floats. (N.A.C.A. Models 51-A, 51-B, 51-C and 51-D. J. R. Dawson and E. D. Hartman, N.A.C.A. Tech. Note No. 678, Dec., 1938.) (63/20 U.S.A.)

CONCLUSIONS.

1. The tank data from the present tests indicate that:—

(*a*) For minimum spray from the float or angle of heel of the seaplane, the planing surface of the float should have a wide stern and a low dead rise.

(*b*) The inclusion of a step, or other equivalent discontinuity, with a properly formed afterbody allows the use of a wide planing surface without sacrificing performance in the drifting condition.

(*c*) The greatest structural loads will be obtained from the float with the most effective planing surface.

2. The wind-tunnel data from the present tests indicate that:—

(*a*) The float that may be set with its chines most nearly in line with the direction of flight in cruising is likely to be the best float from considerations of air drag.

(*b*) All chines or other sharp intersections in the cross section should be avoided except where they are definitely necessary for hydrodynamic reasons.

(*c*) In order to obtain low air drag, it is desirable that the angle of float setting be as small as practicable.

Some Notes on the Measurement of the Flying Qualities of Aircraft. (H. J. van der Maas, Istus Congress, Bern, 1938. Original available in R.T.P.) (63/21 Holland.)

Whilst a considerable amount of research on aircraft performance is available, full scale tests on flying qualities (stability, manœuvrability, control response) are relatively scarce. As a result the flying qualities are mainly judged subjectively by the pilot controlling the aircraft and this may lead to difference of opinion unless absolute criteria are available.

The author shows how a measure of stability (longitudinal lateral and directional) can be obtained from relatively simple flight tests by recording the control surface deflections and angle of banking and constant indicated air speed for various angles of sideslip. An aircraft is thus laterally stable, if an increase in sideslip is accompanied by an increase in the downward aileron deflection on the side facing the lateral wind. Similar simple relationship hold for longitudinal and directional stability. These so-called " static " conditions of stability are not, by themselves, sufficient to determine the motion of an aircraft after a disturbance (oscillation). For these so-called " dynamic " conditions, the flight test requires more complicated apparatus which is at present being developed.

Design and Development of Aircraft Engines. (A. Bagnulo, Riv. Aeron., Vol 14, No. 8, Aug., 1938, pp. 311-320.) (63/22 Italy.)

This is the third instalment of an article dealing with general design problems. The present instalment deals mainly with carburation and distribution. The author is of the opinion that uniform distribution on a multi-cylinder engine can only be achieved by direct metering of the fuel to each cylinder. In the case of spark ignition engines, the metering can be carried out either by means of a separate injection pump or the fuel can be atomised in a small venturi, the exit passage being governed by means of a mechanically operated inlet valve. This constitutes to all intents and purposes the provision of individual floatless carburettors. The author apparently favours the latter scheme since the accurate metering of light fuels of the petrol class by means of a mechanical pump presents difficulties.

Scavenging a Piston-Ported Two-Stroke Cylinder. (A. R. Rogowski and C. L. Bouchard, N.A.C.A. Tech. Note No. 764, November, 1938.) (63/23 U.S.A.)

An investigation was made with a specially designed engine to determine the scavenging characteristics of a large number of inlet-port shapes and arrangements and the optimum port arrangement and timing for this particular type of engine. A special cylinder construction permitted wide variations in timing as well as in shape and arrangement of both the inlet and exhaust ports.

The study of the effect of port shape combinations and timings on engine performance was made using illuminating gas as a fuel. Through variations in inlet-port arrangement and port timings, the value of the scavenging efficiency was increased from an original 44 per cent. to approximately 67 per cent. with a corresponding increase in power. With the optimum port arrangement and timing determined, a large number of performance runs were made under both spark-ignition and compression-ignition operation.

Discharge Characteristics of a Simulated Unit Injection System. (E. T. Marsh, N.A.C.A. Tech. Note No. 676, November, 1938.) (63/24 U.S.A.)

Rate-of-discharge curves that show the discharge characteristics of an injection system having a very short fuel passage are presented. The rate of discharge closely follows the rate of displacement of the injection-pump plunger for open nozzles in which the maximum calculated pressures at the orifice do not exceed a certain value, which is dependent on the particular injection pump. With small orifices and high pump speeds, the rate of discharge does not follow the rate of plunger displacement because the higher discharge pressures result in increased leakage past the pump plunger with a corresponding decrease in discharge rate and in fuel quantity. The rate of discharge is not directly related to the rate of plunger displacement with automatic injection valves having closed nozzles. The types of pump check valve tested did not control the rate of cut-off or the discharge rate but they did affect the injection lag. Increase in valve opening pressure slightly increased the injection lag. Use of the short fuel passage eliminated the formation of secondary discharges.

Automotive Two-Cycle Diesel Engines (with Discussion). (F. G. Shoemaker, J.S.A.E., Vol. 43, No. 6, December, 1938, pp. 485-96.) (63/25 U.S.A.)

The paper is chiefly concerned with the problem of producing an engine that will use the same materials, design practices, manufacturing methods, and mechanical parts as are common practice in production-type petrol engines.

Scavenging is effected in these engines by using piston-controlled inlet ports and poppet exhaust valves in the head.

The author shows how a change in design of the blower to a three-lobe helical-rotor type reduced noise and improved discharge characteristics. Piston cooling is effected by coring out the rim of the piston between the piston crown and the ring belt and cooling the crown directly by oil spray.

In the remainder of the paper the author discusses injection, engine-balance problems and the commercial problems involved in designing the engines and parts to meet a wide variety of applications.

Some Factors Controlling Part-Load Economy. (H. Rabezzana, J.S.A.E., Vol. 43, No. 6, December, 1938, pp. 511-4 and 528.) (63/26 U.S.A.)

Multi-cylinder engines have generally a low economy at light loads. The following are the main disturbing factors: Non-uniform mixture distribution among cylinders; low mixture speed in the manifold at light loads; poor turbulence in the cylinder-head; stratification of the mixture; dilution of the mixture due to the valve timing overlapping the high exhaust back pressure; poor scavenging around the spark-plug gap position; and improper mixture at the spark-plug gap.

Cylinder Cooling and Drag of Radial Engine Installations. (K. Campbell, J.S.A.E., Vol. 43, No. 6, Dec., 1938, pp. 515-528.) (63/27 U.S.A.)

The cowling of an air-cooled radial engine consists, in principle, of two systems in series: (1) The baffle (2) the exit slot. The total pressure drop across the system is approximately equal to the dynamic head of flight, *i.e.*, $\frac{1}{2}\rho v^2$. The ratio of baffle resistance to total resistance depends on the relative effective areas.

Thus, if the slot area is relatively large, the major part of the total available pressure drop occurs at the baffle. With a well-designed exit slot the pressure drop at the slot is recovered and thus the cowling h.p. is mainly due to the baffles. Since this h.p. depends on the volume of air passing, flight at constant indicated air speed is accompanied by an increase in cooling h.p. with altitude unless the exit slot opening is reduced.

On the ground, and during take-off, only the dynamic head of the propeller slip stream is available for forcing the cooling air through the baffles and the cooling may be insufficient even with fully opened exit slot. Attempts have been made to increase this pressure drop by making use of a suction effect near the cowl nose (reverse flow cowls), but experiment has shown that this effect is small and is more than made up by the extra external resistance of a cowl of this type at speed. As an alternative, guide vanes can be installed at the cowl entrance so as to render the rotary component of the slip stream effective. Finally a fan may be installed either behind the propeller and integral with it or as a separate unit (blower cooled installation).

Neither of these schemes has so far progressed beyond the experimental stage, but separate blower cooling of air-cooled engines operating at high altitudes may eventually become necessary.

The Szydlowski-Planiol Centrifugal Supercharger. (A. Métral. Original publication available in R.T.P.) (63/28 France.)

The supercharger consists essentially of a normal centrifugal wheel preceded by three wheels of the axial (propeller) type, all four wheels being keyed to one shaft. The axial blades are of aerofoil section, the first having a symmetrical profile. The diameter of the entry propellers is the same as that of the entry section of the centrifugal wheel. Movable guide vanes are installed in the air intake of the combination by means of which the incidence at the first (symmetrical) propeller can be varied. In this manner the propeller blade assembly can be made to act either as an axial blower (assisting the centrifugal wheel) or as a turbine, with the result of an efficient control of pressure ratio. For very low pressure ratios, break-away of the flow may occur at the turbine and for this reason a second inlet is provided which by-passes the propeller system and gives direct access to the centrifugal wheel.

A constant adiabatic compression efficiency of approximately 80 per cent. is claimed for pressure ratios ranging from 1.3 to 2.5.

Fuels for Aircraft Engines. (F. Seeber, Luftwissen, Vol. 5, No. 9, Sept., 1938, pp. 321-330.) (63/29 Germany.)

The general requirements which an aircraft fuel must meet are the following:—

(1) High octane number.
(2) Good lead response.
(3) Easy vapourisation together with
  (*a*) suitable vapour pressure
  (*b*) high calorific value.
(4) Very great stability when stored.
(5) Perfectly pure and neutral.
(6) No corrosion.
(7) Low freezing point.

The aircraft fuel specifications of Germany, Great Britain, France and U.S.A. are compared.

The octane rating can only be obtained by means of engine tests and the C.F.R. method is now generally used, although ratings above 87 are rather uncertain. Requirements (3) to (7) in the above list can be checked by means of laboratory tests. Seventeen references.

Rating Aviation Fuels in Full-Scale Aircraft Engines. (H. K. Cummings, J.S.A.E., Vol. 43, No. 6, December, 1938, pp. 497-503.) (63/30 U.S.A.)

Data in this report represent work carried out in accordance with assignments made in the first report of the C.F.R. Committee presented at the 1936 Annual Meeting of the Society, as follows:—

1. Establish the validity of the C.F.R. Recommended Procedure for Rating Fuels in Full-Scale Aircraft Engines for fuels above 87 octane number.
2. Conduct full-scale engine tests in the range from 87 octane number to the highest octane number available.
3. Concurrently with assignment 1, develop or revise knock-test methods leading to correlation with full-scale engine data.

The data presented are in accordance with assignments 1 and 2, and the data required for assignment 3 have been obtained in part. Further tests on olefinic fuels are reported.

The Mechanism of Flame Extinction by Means of Dry Powders. (C. Dufraisse and M. German, Compt. Rend., Vol. 207, No. 24, 12/12/37, pp. 1221/1224.) (63/31 France.)

Dry powders are commonly supposed to extinguish flames either by insulating the combustible substance, or cooling the flame or by generating inert gases (steam or CO_2).

The author has carried out experiments on flames of hydrogen, coal gas, methane and carbon monoxide, the minimum concentration of powder required for extinction being measured. The gas burner was placed in the axis of a pyrex tube, the powder being introduced at the base of the tube and carried upwards by the air currents. It appears that certain powders possess a power of extinguishing flames depending on a specific anti-oxygen quality which has nothing to do with either a mechanical or a chemical reaction in bulk (*i.e.*, liberation of inert gases).

Thus a concentration of 5 mg. of potassium chlorate per litre of air will extinguish a CO flame, whilst 50 mg. per litre will extinguish the methane flame. The same powder, however, will act as an accelerator to coal gas and hydrogen flames.

The Hydrodynamic Theory of Detonation. (H. Langweiler, Zeit. Tech. Physik, Vol. 19, Sept., 1938, pp. 271-83. Eng. Abstracts, Vol. 1 (Sect. 4), Nov., 1938, pp. 45-6.) (63/32 Germany.)

The author derives equations containing only directly measurable constants for the quantities involved in the hydrodynamic theory of detonation. The stable detonation speed, D, is revealed as having the lowest possible value in the case of positive material velocity, by finding the minimum of the Du curve (u denotes the speed of the gases of combustion). A study of the conditions of energy and impulse in suspended detonating systems leads to the disclosure of a rarefaction front travelling at a low speed behind the detonation front; its velocity is calculated. The latent energy of the explosive passes into the steadily-growing detonation zone, the region between the detonation front and the rarefaction front. The conclusions drawn from the author's study lead to a new conception of shattering power. His calculations are based upon the behaviour of trinitrotoluene.

Tests on Materials Suitable for Damping Vibrations of Engine Foundations. (K. Sotiroff, Z.V.D.I., Vol. 82, No. 38, 17/9/38, pp. 1120-1.) (63/33 Germany.)

The samples were placed on a concrete floor so as to form the angles of an equilateral triangle. A vibration test machine (Type Losenhausen) was placed on top of the specimen and the whole was surmounted by a stiff iron plate to

which was bolted a vibrograph (Geiger) and a counterweight. By means of the vibration machine the whole system could be forced to undergo either vertical, horizontal or rotary vibration of frequency varying between 0 and 40 vibrations/sec.

The amplitude of the forced vibrations (*i.e.*, resonance of the system) was obtained from the readings of the Geiger Vibrograph.

From the resonance curves both the elastic constants and the damping of the material forming the foundation can be calculated. Of special interest are the experiments with horizontal displacements, since very little was previously known concerning the damping under such conditions (shear). The samples were of uniform dimensions 80 × 80 × 60 mm. ordinary commercial materials such as cork, bonded paper, rubber and their combinations being used.

Effect of Wing Twist Upon Stresses Due to Bending. (H. W. Sibert, J. Aer. Sci., Vol. 6, No. 1, Nov., 1938, pp. 7-9.) (63/34 U.S.A.)

In present design practice no attempt is made to calculate the effect of the twisting moment on a wing upon the tensile and compressive stresses due to bending. A simple formula is derived in this article for the ratio of the tensile and compressive stresses under combined simple bending and wing twist to the corresponding simple bending stresses. This formula involves an unknown constant which must be obtained experimentally from a deflection test on the wing.

New Developments in Seamless Steel Tubing. (W. M. Murray, J. Aer. Sci., Vol. 6, No. 1, Nov., 1938, pp. 20-3.) (63/35 U.S.A.)

The use of welded tubular construction in aircraft has brought about the almost complete replacement of plain carbon steel by chrome molybdenum (S.A.E. X4130) steel tubing. It is the purpose of this research to investigate the properties of tubing made from other alloys, in particular chromium-nickel-molybdenum steel, with a view to finding something with more advantageous properties than the material now employed.

The tensile properties of two sizes of S.A.E. 4340 tube have been determined and the effect of welds has been investigated by strut compression tests. A comparison has been made between the strength of plain tube sections and those possessing straight and V welds and the effect of a right angle connection has been determined through tests on T-shaped specimens.

Approximate Stress Analysis of Multi-Stringer Beams with Shear Deformation of the Flange. (P. Kuhn, N.A.C.A. Report No. 636, 1938.) (63/36 U.S.A.)

The problem of skin-stringer combinations used as axially loaded panels or as covers for box beams is considered from the point of view of the practical stress analyst. By a simple substitution the problem is reduced to the problem of the single-stringer structure, which has been treated in N.A.C.A. Report No. 608. The method of making this substitution is essentially empirical; in order to justify it, comparisons are shown between calculations and strain-gauge tests of three beams tested by the author and of one compression panel and three beams tested and reported elsewhere.

For sheet with individual stringers, experimental studies on individual panels have usually led to the conclusion that the best efficiency is obtained by making the skin as thin as possible, consistent with practical considerations. If the shear deformation in the actual structure is taken into account, it becomes evident that this conclusion will often require serious modification. It might be worth while in some cases to investigate the effect of thickening the skin near the wing tip, where the shear deformations are largest and, therefore, easiest to decrease.

The Twisting of Thin-Walled Stiffened Circular Cylinders. (E. Schapitz, Lilienthal Gesellschaft fur Luftfahrtforschung Jahrbuch, 1936, pp. 94-132. Available as Translation T.M. 878.) (63/37 Germany.)

On the basis of the present investigation of the twisting of thin-walled, stiffened circular cylinders, the following conclusions can be reached:—

1. There is as yet no generally applicable formula for the buckling moment of the skin.

2. The mathematical treatment of the condition of the shell after buckling of the skin is based upon the tension field theory, wherein the strain condition is considered homogeneous.

3. The twisting tests in the DVL on stiffened circular cylinders were accompanied by stress measurements on the skin, the stringers, and the bulkheads. In addition, the strains on the shell surface were recorded and the angles of twist of the shells measured. The comparison of the theoretical with the experimental results disclosed that, on assuming a complete tension field, the imputed angles of twist were computed much too great, and the stresses in the stringers and bulkheads too high, while on assuming an incomplete tension field the theoretical results could be largely reconciled with the experimental results by suitable choice of the proper constants for the " stretching " of the tension field.

4. Applying the method to the range of twisting moment at failure, the latter can be predicted sufficiently exactly from buckling-bending tests on panels. For thin skin and strong stiffeners the calculation for complete tension field affords sufficiently accurate results; but if the skin is thick and the stiffeners weak, this calculation results in an underestimate of the ultimate twisting strength, hence an accurate calculation postulates an incomplete tension field.

The Effect of the Speed of Stretching and the Rate of Loading in the Yielding of Mild Steel. (E. A. Davis, J. Applied Mech., Vol. 5, No. 4, Dec., 1938, pp. 137-40.) (63/38 U.S.A.)

The phenomena occurring at the upper and lower yield point in mild steel are not yet fully understood. This paper is an attempt to study some of these phenomena and to correlate them with the facts already known about the first yielding of this unique material.

In order to investigate the rate of loading on the yielding of mild steel a machine was designed in which the amount of increase in load per unit time could be held constant regardless of the rate of strain. Results of tests are presented in which the rate of loading for separate tests was changed by a maximum ratio of 1 to 21,000. The effect of rate of loading was studied on four different shapes of test specimens.

Factors affecting the initial yielding of mild steel and their influence on the shape of the stress-strain diagram are discussed. These factors include the effect of the speed of deformation and of stress concentration upon the stress at which yielding takes place. The manner in which localised yielding affects the stress distribution in the bar and changes the actual strain rate is also described.

Fundamentals of Three-Dimensional Photo-Elasticity. (M. Hetényi, J. App. Mech., Vol. 5, No. 4, Dec., 1938, pp. 149-55.) (63/39 U.S.A.)

The method of three-dimensional photoelasticity is based on the experimental fact that samples of phenolic resins, such as Bakelite, Marblette, and Trolon, when annealed in a loaded condition show a complete preservation of (*a*) the elastic deformation and (*b*) the accompanying birefringence produced by the loading at the annealing temperature. After presenting a historical review of the method, the author discusses the current theory of the molecular structure of phenolic resins by which the phenomena observed in the annealing procedure can be explained. Test results are given which prove the elasticity of Bakelite at elevated temperatures. Applications of the method are also discussed.

Steady Oscillation of Systems with Non-Linear and Unsymmetrical Elasticity. (M. Rauscher, J. App. Mech., Vol. 5, No. 4, Dec., 1938, pp. 169-77.) (63/40 U.S.A.)

Steady forced oscillations are reduced to free undamped oscillations of the same amplitude. The reduction is accomplished by changing the excitation from a time function $F(t)$ into a space function $F(x)$ through the assumption that x and t are related as in a free motion. By combining $F(x)$ with the elastic restoring force $E(x)$, a new effective $E(x)$ is obtained, to which there corresponds a new "free" motion, which, in turn, furnishes a second approximation for the relation between x and t, and hence a new function $F(x)$. A new effective $E(x)$ and a new free motion are then found; and the cycle is repeated until the relation between x and t ceases to change. The frequency of the forced motion at the assumed amplitude is then known. In general, the process converges rapidly. The accuracy can be checked at any stage of the work. A general criterion of the stability of the motions is offered.

Calculation of Stresses and Natural Frequencies for a Rotating Propeller Blade Vibrating Flexurally. (W. Ramberg and S. Levy, J. of Res. Bureau of Standards, Vol. 21, No. 5, Nov., 1938, pp. 639-69.) (63/41 U.S.A.)

The present paper extends the method of computing the natural modes of flexural vibration of a non-rotating propeller blade which was described in RP764 to blades that rotate as in actual flight. The resulting integral equations were solved for two aluminium-alloy propeller blades of typical design vibrating with the fundamental mode and with the second harmonic mode and rotating at speeds covering the range of service speeds. The effect of rotation on the stress distributions and on the natural frequencies was obtained for the two extreme end conditions of rigid clamping at the hub and no clamping at the hub. Rotation was found to have a small effect (up to 13 per cent.) on the maximum stress per unit tip deflection and was found to shift the maximum toward the hub. For the determination of critical speeds, the natural frequencies were shown to follow conveniently from Lord Rayleigh's energy method by making use of the solutions for no rotation outlined in RP764. The effect of initial twist on the flexural frequencies of the blade was found to be small compared with the effect of changes in clamping at the hub. Changes in clamping may change the frequency up to 13 per cent. A correction to RP764 is noted in this connection. Both the stress distribution and the natural frequencies of a given propeller blade may be calculated from those obtained for a model blade by means of two model rules developed by Theodorsen.

The Testing of Welds. (R. Smallman-Tew, Weld. Ind., Dec., 1938, pp. 399-405. Metropolitan Vickers Tech. News Bulletin, No. 640, 23/12/38, p. 4.) (63/42 Great Britain.)

The author discusses tests on welds under the headings "Destructive" and Non-Destructive" tests. He describes fully the non-destructive tests such as visual examination, X-ray, magnetic, acoustic and partial pressure or loads tests. He continues by describing types of destructive tests such as chemical analysis, corrosion, microscopic examination, mechanical—tensile, compression, shear, bend and alternating tests—fatigue, impact, hardness, pressure, abrasive and hammer tests. He concludes the article by discussing testing requirements, the necessity for laboratory and shop tests, and the necessity for "planned testing."

Illustrated with 4 photographs and 3 diagrams.

Tests of Welds in Alloy Steels. (S. F. Yasines and F. C. Fair, J. Am. Welding Soc., Vol. 17, No. 9, Welding Research Suppt., Sept., 1938, pp. 28-34. Eng. Absts., Vol. 1, No. 11 (Sect. 2), Nov., 1938, p. 157.) (63/43 U.S.A.)

The authors observe that the main purposes of the research described in which tests were made on four kinds of alloy steels, butt-welded with two different types

of electrodes, were (1) to determine the relative hardness and impact strength of the deposited metal, the heat-affected zones, and the base metal; (2) to ascertain whether a definite relationship exists between hardness and impact strength; (3) to study the effect of heat treatment. The welds were 60° single-bevel welds in ½in. thick plates. Stress relieving was carried out for six hours at a temperature of 600°F. Impact tests were made in a standard Izod impact machine, and hardness was determined by a Rockwell machine. The results indicated that the welds gave the weakest sections as regards impact strength; that heat treatment effected some improvement in the impact strength of all zones; and that no definite relationship could be established between hardness and impact strength.

Fatigue Strength of "Fillet" and "Fusion Welded" Connections. (A. Thum and A. Erker, Zeit. Ver. deu. Ing., Vol. 82, 17/9/38, pp. 1101-6. Eng. Abstr., Vol. 1, No. 11 (Sect. 2), Nov., 1938, pp. 157-8.) (63/44 Germany.)

The authors describe experiments carried out with specimens of T-section having a web 19⅝in. wide and 0.59in. thick, welded to the flange by means of (1) a fillet on each side of the web; (2) a fusion weld. In the latter case the flange was formed with a longitudinal projecting rib to which the web was welded. Fatigue-strength results for both types of welded seam, in the untreated state, when annealed, and when mechanically treated, are plotted in curves which indicate that under 10^7 repetitions of load, a strength equal to that of parent metal was attained when the fillets were trimmed to a smooth finish and the edges were rolled with a pair of disks, one on each side of the web, the edge of the disks being rounded to a radius of 2.5 mm. (0.1in.) and acting under a pressure of 1,650lb. The disks were held in a frame attached to a planning machine, on the table of which the welded specimen was placed and submitted to the rolling treatment during four to-and-fro movements of the table.

X-Ray Measurement of Stress in Steel Bars Subjected to Bending Stresses Exceeding the Yield Point. (F. Bollenrath and E. Schiedt, Z.V.D.I., Vol. 82, 17/9/38, pp. 1094-1098. Eng. Abstr., Vol. 1, No. 11 (Sect. 1), Nov., 1938, p. 118.) (63/45 Germany.)

The authors describe experiments, in which test bars of square, trapezoidal, and triangular section were submitted to bending moments. The calculated stresses in the outer fibres were compared with the stresses deduced from the lattice spacing of the crystals, as determined by X-ray examination. The results indicate that for a bar ⅜in. square, containing 0.04 per cent. C, the yield point was attained at 15.2 tons per sq. in. Increase in the bending moment to a calculated stress of 17.6 tons per sq. in. revealed a lattice distortion corresponding with a stress of 12.9 tons per sq. in. Inherent stresses in the bar after successive unloadings ranged between ± 1.2 tons per sq. in. until the yield point was attained. Bending moments producing 16 tons and 17.5 tons per sq. in. tension, revealed inherent compressive stresses of 3.5 tons and 4.4 tons per sq. in. when the load was released. The authors state that the yield point is not higher under bending than under tension, and that bending moments from which the calculated stresses are in excess of the yield point reveal stresses under X-ray examination which are lower than the yield point, indicating that the excess portion of the stress is transferred to the neighbouring fibres of the cross section.

The D.V.L. Exhaust Gas Analyser. (H. H. Berg, A.T.Z., Vol. 41, No. 17, 10/9/38, p. 455.) (63/46 Germany.)

The proper adjustment of carburettors and injection pumps requires a knowledge of the mixture strength in the cylinder. Measurements of air and fuel supply need rather complicated installations and an accurate and continuous reading of the rate of fuel supply is not easy. Since mixture strength and composition of exhaust gas are intimately connected, a continuous exhaust gas analyser gives the required

information in a very simple manner. The apparatus evolved by the D.V.L. depends on changes in the thermal conductivity of the exhaust with change in composition and after calibration on an actual engine, the excess air coefficient can generally be obtained to within ± 1 per cent., the lag being of the order of five seconds. The D.V.L. instrument is compensated for altitude and change in temperature. An efficient water separator is incorporated in the design and it is stated that the analyser will function over long periods in aircraft without requiring any attention. The readings are taken on a pointer instrument and fuel adjustment for maximum range is thus an easy matter.

Viscous Flow Air Meters. (The Engineer, Vol. 166, No. 4,329, 30/12/38, p. 743.) (63/47 Great Britain.)

This instrument, known as the Alcock viscous flow air meter, is designed to eliminate the serious errors which arise when pulsating air flows are measured in kinetic air meters of the orifice, Venturi and other types. These errors are partly accounted for by " root-mean-square " effects and partly by the flow in and out of the manometer, set up by pressure variations.

In the viscous flow air meter, the meter element is a honeycomb of long triangular passages, 3in. long and 0.017in. in height. Within the working range, the flow through these passages is viscous, and the resistance of the element is, therefore, directly proportional to the velocity; this fact automatically eliminates the " root-mean-square " error.

Electric CO_2 Meter with Bar-Shaped Heating Elements. (G. Heidtkamp, A. E. G. Mitt, Dec., 1938, pp. 562-5. Metropolitan Vickers Technical News Bulletin, No. 641, 30/12/38, p. 9.) (63/48 Germany.)

The author describes an improvement on the platinum wire elements hitherto used in CO_2 meters, namely thin bars of sintered alumina heated by a wire inside. The advantages claimed are that current-carrying parts of the apparatus do not come into contact with the flue gas and that the test wires are protected from chemical attack. He discusses conditions relative to the operation of such bars, the temperature distribution along a bar, the lag in indication of the CO_2 transmitter, etc.

Illustrated with 5 diagrams and 1 photograph.

Icing of Aircraft Antenna Wires. (G. L. Haller, J. Aer. Sci., Vol. 6, No. 1, Nov., 1938, pp. 27-8.) (63/49 U.S.A.)

More data under conditions of higher wind velocity are needed before definite conclusion can be made regarding a critical icing angle, but due to the limitations of the test equipment these conditions cannot be obtained at the present time.

In general, the results that antenna wires on aircraft should be installed with angles from the wind stream of less than 15° to 20° in order that the ice load be reduced and the ice formation will be as unstable as possible.

Lightning Discharge to the Empire State Building. (K. B. McEachron, Electrical Engineering, Dec., 1938, pp. 493-505, 507. Metropolitan Vickers Technical News Bulletin, No. 641, 30/12/38, p. 4.) (63/50 Great Britain.)

In this article the author describes a series of investigations undertaken in New York on lightning discharges to the Empire State Building. A description of the photographic equipment—cathode ray oscillograph, electro-magnetic oscillograph, Boyes camera and two rotating lens cameras—is given and the results are discussed. By means of photographic and oscillographic records, the author shows the different types of discharge and discusses the polarity, duration, charge transferred, mechanism of the discharge leaders, de-ionisation time, branching, discharge path, upward streamers, thunder, streamer currents and maximum currents.

Illustrated with 8 photographs, 9 diagrams and 2 tables.

Heat Transfer to Boiling Liquids. (F. H. Rhodes and C. H. Bridges, Ind. and Eng. Chem. (Industrial Edition), Vol. 30, No. 12, December, 1938, pp. 1401-6.) (63/51 U.S.A.)

The results of these experiments indicate that the manner of boiling of a liquid at the surface of a solid and the observed unit rate of heat transfer are determined largely by the ease with which the liquid wets the solid. Relatively small amounts of certain substances in solution or in suspension in the liquid may have a great effect in altering the manner of boiling and in changing the unit rate of heat transfer.

Some of the large variations in the evaporative capacities of evaporators operating under apparently similar or comparable conditions may be due to the presence of small amounts of contaminating substances that change the wettability of the solid by the liquid. The observed variation in the effects of various salt solutions in the quenching of steel may be caused by variations in the ease of wetting of the metal by the solution.

The Photography of Airscrew Sound Waves. (W. F. Hilton, Proc. Roy. Soc., Series A, Vol. 169, No. 937, 22/12/38, pp. 174-90.) (63/52 Great Britain.)

An experimental technique has been developed for photographing the shock waves generated by an airscrew at all speeds above a certain critical speed. A modified form of spark photography was employed, and photographs were obtained for the first time of the airscrew sound wave system at tip speeds ranging from 0.83 to 1.2 of the velocity of sound.

The photographs also reveal a tailing vortex from the blade tip, and an eddying wake behind the blade. These vortices and eddies are more distinct at high speeds than at low, but there is no definite lower limit to the speed at which they can be photographed.

A method is given for calculating the pressure amplitude of these shock waves from measurements of the width of the image. The wave velocity has been calculated from the photographs, and is found to be slightly greater than that of small amplitude waves.

A method of calculating the shape of the waves is examined, but no theoretical indication of a wave front at tip speeds less than the speed of sound is given, whereas a very definite wave front exists down to speeds as low as 0.85 of sound velocity. The problem of noise reduction in aircraft is discussed.

The London Television Service. (T. C. Macnamara and D. C. Birkinshaw, J. Inst. Elec. Eng., Vol. 82, No. 504, Dec., 1938, pp. 729-57.) (63/53 Great Britain.)

The paper is divided into six parts:—

Part 1 touches briefly upon the history of television development in this country.

Part 2 deals with the recommendation of the television committee that a station for transmitting high-definition television should be established, and it discusses various factors upon which the subsequently appointed Television Advisory Committee based its decisions regarding the choice of the Alexandra Palace site, the operating wavelengths, and standard of definition.

Part 3 describes the arrangement of studios and apparatus rooms at the Alexandra Palace Station.

Part 4 describes the layout and arrangement of the control room and transmitter equipment installed for the vision and accompanyng sound transmissions.

Part 5 is concerned with the plant developed to enable current events and other programme items taking place at some distance from the Alexandra Palace to be televised.

Part 6 is a brief consideration of the reception results of signals from the Alexandra Palace since the beginning of the service, and embodies the result of single surveys made in the vicinity of, and at distances from, the station.

Finally, the various types of television receivers and aerials are discussed.

The Centralised Control of Public Lighting and Off-Peak Loads by Superimposed Ripples (with Discussion). (H. P. Barker, J. Inst. Elec. Eng., Vol. 82, No. 504, Dec., 1938, pp. 823-4.) (63/54 Great Britain.)

It is the author's purpose in this paper to discuss the problems of collective control on modern supply networks, to examine various alternative methods, and to explain how, by the aid of superimposed high-frequency signals, any distribution network may be used as a signalling system which will enable a supply undertaking to exercise remote control of consumer circuits from its own power station.

The special application of superimposed control in war time for the extinction of public lighting and for the dissemination of warning signals is briefly discussed.

Rectangular Hollow-Pipe Radiators. (W. L. Barlow and F. M. Greene, Proc. Inst. Rad. Eng., Vol. 26, No. 12, Dec., 1938, pp. 1498-1519.) (63/55 U.S.A.)

Two principal results of this research are the following: (1) the development of a theory for the radiation from open hollow pipes; and (2) the experimental verification of this theory. Another result is the justification of the application of Huygen's principle when used in conjunction with the Hertzian vector to radiation problems where the dimensions of the system are comparable to the wavelength. The authors believe to have shown that the open rectangular pipe is a radiating element for ultra-short waves possessing several advantages over conventional types of antennæ. The absence of insulating members, the freedom from stray radiation, and the absence of difficult amplitude and phase adjustments are examples of these features.

Electromagnetic Waves in Hollow Tubes of Rectangular Cross Section. (L. J. Chu and W. L. Barrow, Proc. Inst. Rad. Eng., Vol. 26, No. 12, Dec., 1938, pp. 1520-55.) (63/56 U.S.A.)

The theory of the transmission of electromagnetic waves in hollow conducting pipes of rectangular cross section is derived for perfectly conducting and imperfectly conducting materials. Special attention is given to the type of wave that has only one transverse and everywhere parallel component of electric intensity, and the results of experiments on this wave are reported. Expressions for the attenuation of the different types of waves allow comparisons to be made with corresponding waves in a pipe of circular cross section. In a rectangular pipe no wave has been found whose attenuation decreases indefinitely as the frequency is increased as does the H_0 wave in a circular pipe.

Production of Electricity by Direct Combustion. (The Engineer, Vol. 166, No. 4326, 9/12/38, p. 636.) (63/57 U.S.A.)

Fuel or gas cells generate E.M.F. when oxygen and a combustible gas are in contact with suitable electrodes and a suitable electrolyte in such a manner that the gases cannot mix. Such cells have been known in the laboratory for some time. According to American claims a new version of this cell appears to have commercial possibilities. According to the patent granted to H. H. Greger in 1934, the general claims are as follows:—

The process of generating electricity which comprises introducing a fuel gas into a gas cell at the gas electrode thereof, where it contacts an electrolyte comprising a fused mixture of alkali metal and alkaline earth metal carbonates and halides, and reacts chemically therewith, releasing electrical charges which are imparted to the gas electrode, and simultaneously introducing an oxygen containing gas at the oxygen electrode of the cell, where it contacts the electrolyte and reacts chemically therewith, thus releasing electrical charges which are imparted to the oxygen electrode, the cell being operated at a temperature between 700°C. and the melting point of the electrolyte. The process of generating electricity by

oxidising carbon monoxide and hydrogen at the gas electrode and simultaneously reducing oxygen by reaction with positively charged ions at the oxygen electrode of the cell.

The melting point of the mixture of salts forming the electrolyte is below 700°C., and the electrolyte is said to comprise a fused mixture of sodium carbonate, potassium carbonate, barium carbonate, sodium chloride, potassium chloride, barium chloride, sodium fluoride and potassium fluoride. Numerous mixtures and combinations of these chemicals may be made, and some of these mixtures are listed in the patent specifications as samples, the patent not being limited to any definite or specific combination.

Notes on German Popular Aviation during 1938. (Inter. Avia., No. 603, 20/12/38, p. 12.) (63/58 Germany.)

The membership is broadly divided into three classes:—

	Membership.
1. Flieger Jungvolk	63,000
2. Hitler Youth	90,000
3. N.F.S.K.	52,000

1. The F.J. comprises young boys (below 14).
2. Of the Hitler Youth, 7,500 have received gliding training.

9,000 hold " A " licence
5,000 ,, " B " ,,
1,000 ,, " C " ,,

3. The N.F.S.K. own 842 machines and have flown 2.8 million kilometres during the year. Sixty balloons are also available for training purposes.

Popular Aviation in France. (Inter. Avia., No. 603, 20/12/38, pp. 12-13.) (63/59 France.)

Three age classes are distinguished:

14-16 years (preparatory)
16-18 years (gliding)
18-21 years (power flight).

During 1938, 2,333 " I " licences were issued and 95 pupils were passed to Istres and other centres for further training. Of these seven received the military licence.

The total expenditure for the year was 80 million francs.

Large Wind Power Generating Plants. (H. Witte, E.T.Z., 22/12/38, pp. 1373-6. Metropolitan Vickers Technical News Bulletin, No. 641, 30/12/38, p. 11.) (63/60 Germany.)

On the basis of the knowledge hitherto gained on air currents, the problem of large wind power generating plants is investigated from the economic standpoint. The utilisation of the energy of the wind for the generation of power would release large quantities of coal for other purposes and would also relieve the foreign exchange situation of Germany. In a further part of his article to be published later the author will discuss the practical realisation of such generating plants, and will describe the design of a ring generator.

Illustrated with 5 diagrams.

LIST OF SELECTED TRANSLATIONS.

NOTE.—Applications for the supply of copies of translations mentioned below should be addressed to the Under-Secretary of State, Air Ministry (R.T.P.), Berkeley Square House, W.1, and will be supplied, free of charge, as far as availability of stocks permit. Suggestions concerning new translations will be considered in relation to general interest and facilities available.

AERODYNAMICS AND HYDRODYNAMICS.

TRANSLATION NO. AND AUTHOR.		TITLE AND JOURNAL.
789	Kaul, H. W. ... ... Pretschner, W. ..	*Measurement of the Normal Force on the Horizontal Tail Plane and Elevator During Flight.* (Yearbook of German Aeronautical Research, Vol. 1, 1937, pp. 154-63.)
794	Schmidt, R.	*Experimental Contribution to the Problem of "Downwash and Slipstream."* (Yearbook of German Aeronautical Research, 1937, Vol. 1, pp. 139-153.)
795	Gebelein, H.	*The Theory of Two-Dimensional Potential Flow Round an Arbitrary Aerofoil.* (Ingenieur Archiv., Vol. 9, No. 3, June, 1938, pp. 214-240.)
796	Fomina, N. N. ...	*Calculation of the Frictional Resistance of a Family of Bodies of Revolution According to the Exponential Law.* (Aeron. Eng., U.S.S.R., No. 7, July, 1938, pp. 61-5.)

ARMAMENTS AND THEORY OF WARFARE.

738	Heinkel, E.	*The Heinkel He. 112 Single-Seater Fighter.* (Descriptive Pamphlet published by Ernst Heinkel—Flugzeugwerke.)
778	——	*The Attack of Aerial Bases.* (Rev. de l'Arm. de l'Air, No. 108, July, 1938, pp. 723-5.)
783	Vasilovski & Shvetsov	*The Attack of Rail Heads and Front Line Supply Stations by Means of Light Bombers.* (Air Fleet News, U.S.S.R., No. 6, June, 1938, pp. 28-35. Luftwehr, Vol. 5, No. 9, September, 1938, pp. 361-5.)
784	Serra, A.	*Italian Opinions on the Armament of the Fighter—Medium or Heavy Guns.* (Luftwehr, Vol. 5, No. 7, July, 1938, pp. 271-3.)
785	Filloux, L.	*Application of Statistical Analysis to Ballistic Problems.* (Revue d'Artillerie, Vol. 120, Dec., 1937, pp. 429-57.)
786	Biani, V.	*The Defence of Aerial Bases (from the Italian).* (Luftwehr, Vol. 5, No. 6, June, 1938, pp. 238-42.)
788	Rehder, D.	*The Present State of Coastal Defence.* (W.T.M., Vol. 42, No. 8, August, 1938, pp. 350-65.)
790	Lohle, F.	*Air Reconnaissance at Night.* (W.T.M., Vol. 42, No. 3, March, 1938, pp. 125-33, and No. 4, April, 1938, pp. 170-8.)

TRANSLATION NO. AND AUTHOR.		TITLE AND JOURNAL.
799	Kreidel, D.	*Experimental Methods for the Testing, Investigation and Development of Automatic Weapons (Machine Weapons).* (Beiträge zur Ballistik und Technischen Physik. Published by J. A. Barth, Leipzig, 1938, pp. 128-38.)
		ENGINES AND ACCESSORIES.
781	Koch, E. ... ... Sommer, P.	*New Surfaces for Pistons.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 2, 1937, pp. 193-7.)
787	Bollenrath, F. ... Bungardt, W. ...	*On the Thermal Conductivity of a Few Piston Alloys at High Temperatures.* (Jahrbuch der Deutschen Luftfahrtforschung, Vol. 2, 1937, pp. 190-2.)
793	Gothert, B.	*The Air Resistance of Aircraft Radiators Under Conditions of Heat Transfer (Comparison of Theory and Experiment).* (L.F.F., Vol. 15, No. 9, 10/9/38, pp. 427-44.)
801	Ragazzi, P. ... ... Maiorca, S.	*Notes on the Methods of Calculation of the Performance of Engines at High Altitudes.* (L'Aerotecnica, Vol. 18, No. 5, May, 1938, pp. 609-22.)
		METEOROLOGY.
791	Mirles, A.	*The Icing Problem on Aircraft.* (Pub. Sci. et Tech. du Ministere de l'Air, B.S.T., No. 78, April, 1938.)
		INSTRUMENTS.
800	Elia, L.	*The Climb and Descent Indicator and its Functioning at High Altitudes.* (L'Aerotecnica, Vol. 18, No. 5, May, 1938, pp. 646-54.)
		FUELS.
780	Kessler	*Comparative Tests of Motor Fuels by Engine and Laboratory Methods.* (Oel und Kohle, Vol. 14, No. 17, 1/5/38, pp. 341-50.)
		MATERIALS AND ELASTICITY.
779	——	*Symposium of Papers on the Fundamentals of Material Strength Investigation, Presented at the General Meeting of the V.D.I., Stuttgart,* 1938. (Z.V.D.I., Vol. 82, No. 21, 21/5/38, pp. 657-9.)

REVIEWS.

CONQUEST OF THE SKIES.

Peter Merin. John Lane. 1938. 12/6 net.

This is a translation from the German of the author's "Eroberung des Himmels." It is a history of the conquest of flight from the earliest times to the present day. The story is largely written in the form of a great flight through the ages by the reader in company with the author, who has collected an astonishing amount of information in a small compass. The story is most pleasantly told and as far as the reviewer has been able to check it, accurate. Here is the astonishing aerial panorama from the fabled winged Ra, the Egyptian sun-gods, Astarte, the mistress of the Syrian sky, and Hermes, the divine messenger of the Greeks to the Wright Brothers, Alcock and Brown, the Explorer II, and rocket flight.

An excellent gift book to rouse the imagination and interest in the great story of flight.

PHYSICAL SCIENCE IN MODERN LIFE.

E. G. Richardson, B.A., Ph.D., D.Sc. The English Universities Press, Ltd. 1938. 8/6 net.

Dr. Richardson is to be congratulated on his book, from the preface to the index. "If you have wondered," he says in his preface, "how an aeroplane flies—what constitutes a quicksand—why it is usually necessary to shake an embrocation, but not a mayonnaise—how a man can glide for four hours in an engineless aircraft—what limits clarity on the television screen and power in broadcasting stations—how a fish swims—shall we have trips to the moon?; these are some of the subjects on which I intend to discourse."

The author has discoursed well. Chapter I deals with streams and eddies, the familiar flow of air over various shaped bodies. Chapter II covers vibrations and waves. Here is explained why pouring oil on troubled waters has its magic effect, why certain sounds are musical and other interesting phenomena. Chapter III is concerned with sound waves, upon which Dr. Richardson is himself an authority, and is naturally followed by Chapter IV on super sound, one of the most interesting in the book, chapters on colloids, heat, light, elasticity, sensation and reaction. The final chapter deals with the Exploration of the Stratosphere.

Physical Science in Modern Life is a mine of interesting information and the more one digs into the mine the more one is astounded by the discovery of the glittering gems of man's scientific progress.

THE AIR AND ITS MYSTERIES.

C. M. Botley, F.R.Met.S. G. Bell and Sons, Ltd. 1938. 8/6 net.

The rapid increase in flying all over the world has brought with it a very natural desire on the part of many people to know something more about the medium in which it takes place. Miss Botley has steered a middle course between a textbook of meteorology and an ultra popular book which tells little in much

space. As Sir Richard Gregory says in his preface, "Miss Botley traces the growth of the highways of the air and of flight along them, and her story of this and other achievements has always the human touch which saves it from being placed in the obviously instructional class of simplified textbook to which many adult readers object."

Miss Botley has written a most interesting book and in a way which leads the reader on from page to page, even though he or she may have quite a good working knowledge of meteorology. Whether it is rain, hail, snow, or sunshine, the cause and effects are explained in a way which is remembered. Description is interspersed with anecdote. To quote: "Very often, however, especially in winter, cold-front storms only develop enough energy to produce a single flash and peal, which none the less, because of its suddenness, is often very disconcerting. No doubt it was this type of storm that broke over Westminster Abbey during the coronation service of Stephen in December, 1135, and so flustered Archbishop William de Corbeine that he not only dropped the sacred water, but forgot to give the king the kiss of peace and benediction."

In a book of this kind it is perhaps a little invidious to pick out one chapter more than another, but the reviewer cannot refrain from saying that to him the most interesting chapter is the last, "Towards the Unknown Regions." Here the stratosphere and the upper air generally are described.

There is an excellent index and a note on the books to read. There is little doubt that many who read Miss Botley's book will be inspired with the necessary enthusiasm to delve deeper into the mysteries of the air.

METAL SPRAYING.

Revised and largely re-written by E. C. Rollason, D.Sc. Published by Charles Griffin and Co., Ltd. Price 15/-.

This is the second edition of this book which was originally written by T. H. Turner, M.Sc., and N. F. Budgen, M.Sc., it contains a comprehensive account of the development of metal spraying from its origin about the year 1882 to the present.

The process is one that always has a certain fascination. In one of the early aero exhibitions a wooden aeroplane propeller was shown, coated with copper by this method, and as far as the eye could see the coating was continuous and perfect. It seemed that wood sprayed with copper would be an excellent propeller material, but it was soon found that the copper did not protect the wood from moisture, in fact it was less effective in this direction than a coat of good varnish. It seems that this defect is still existent, in fact the author, when discussing copper sprayed wood, states that the moisture absorption does not differ appreciably from unprotected wood.

This porosity of the coating is usually the difficulty with this process. It is certainly true that in certain applications, such as bearing surfaces on shafts, the porosity is an advantage, as it tends to hold oil, but in most cases it is a serious disadvantage, and although it may be possible in certain instances to destroy the porosity by heat treatment, this latter is an additional operation and in large pieces may be impossible.

On the other hand, large objects may be coated by this process when other methods are not possible, and zinc sprayed coatings seem to give a considerable protection to steel. At the same time it is not easy to visualise that sprayed coatings are likely to be much used in aircraft, for the pieces are usually small and a better coating can be produced by some alternative method. But for decorative purposes and special parts sprayed metal has a large field of its own.

The author has dealt with the subject thoroughly, and there are a large number of good illustrations, but when he simply refers to the possibility of forming an insoluble chemical compound in the pores of the sprayed metal by means of a polymeric change in certain organic compounds he merely whets the reader's interest without satisfying it. The book also contains an excellent discussion of other methods of applying metallic coats to metals which will be of interest to many.

INCHLEY'S THEORY OF HEAT ENGINES.

Edited and revised by H. Wright Baker, D.Sc. Published by Longmans, Green and Co., Ltd. Price 14/-.

This is the fourth edition of this book and new matter has been added while the chapters dealing with kinematics and dynamics have been dropped and the conceptions of thermodynamics have been introduced in order to assist the student to visualise the mechanism of the various processes.

The first part of the book, after the thermodynamic introduction, deals with the different theoretical heat cycles. This is followed by a chapter on entropy and after a few miscellaneous matters there is a discussion on hot air engines, air compressors, followed by seven chapters on various forms of steam engine and matters concerning them. The last chapter only is devoted to the internal combustion engine.

As a statement of thermodynamics and its application to practical problems this book is excellent and is specially recommended to those engaged in engine design. The fact that a large portion of the book is devoted to steam is not really a disadvantage, for the extreme simplicity of this fluid compared with the complex mixture of gases and continual change of state associated with combustion in an engine cylinder, enable the theoretical considerations to be developed in terms of steam with much greater ease.

These considerations are just as applicable to the internal combustion engine, but are much more difficult to apply, but it is to be expected that with the growth of our knowledge on combustion they will become of greater assistance to the designer.

THE FINE STRUCTURE OF MATTER. Part II.

By C. H. Douglas Clark, D.Sc. Published by Chapman and Hall, Ltd. Price 15/-.

This is the second part of a work which is concerned with atomic and molecular theory. The author points out that the extremely rapid advance in this subject which has occurred in recent years has been due to research along many different lines and that, consequently, the research worker in a specialised branch has difficulty in keeping in touch with the results of others. This book has therefore been written for the purpose of correlating the results of these diverse researches.

This part deals mainly with the Bebye theory of polarisation, Fajan's theory of deformation and the derivation and meaning of dipole moments, and includes a detailed account of work on the Kerr effect. Except for a few mathematical proofs in the appendix, the treatment is mostly non-mathematical, and each chapter is accompanied by a list of references which add greatly to the value of the book. There is also a list of authors to whose work reference has been made.

This particular subject, speaking generally, is not at the present time of great interest to the engineer. But there is no doubt that in the properties of the atom or molecule there resides the clue to the properties of engineering materials.

The time will come when the properties of alloys will be explicable in terms developed from the theories dealt with here, and a rapid improvement in structural materials must follow.

THE FINE STRUCTURE OF MATTER. Part III.

By C. H. Douglas Clark, D.Sc. Published by Chapman and Hall, Ltd. Price 15/-.

This is the third part of this work and it deals principally with modern knowledge on spectroscopy especially with reference to newer adaptations of the quantum theory, and it is of great interest to learn how the interpretation of spectral phenomena is dealt with in the light of modern theory. But at the same time, as the author points out, much has been discovered by chemists, and more might be added by engineers, which still awaits interpretation. There does not seem to be any doubt, and this opinion is strengthened by the perusal of this volume, that this particular branch of knowledge will in the future make important contributions to applied science. At present it may be regarded as having surmounted its earlier difficulties and to be making rapid progress in explaining spectral and other phenomena. Further development which is certain to follow may have the most far reaching effects on the materials used by industry and may explain many unsolved problems which are at present dealt with by rule of thumb methods. It is a subject with which every engineer should keep in touch.

CARNET DE SIGNAUX a l'usage de la Navigation Aérienne, établi conformément à la Convention Aérienne de 1919 et du Code International de Signaux. (Handbook of Signals used in Air Navigation in accordance with the Air Convention of 1919 and the International Code of Signals.)

Commission Internationale de Navigation Aérienne, 60bis Avenue d'Iéna, Paris, 1938. Publ. by Louis Bellenaud et Fils, Fontenay-aux-Roses. 159 pp. with num. fig. and coloured plates. Price 40 francs.

This handbook of signals has been specially arranged to facilitate quick and easy use by the crews of aircraft, and by its practical layout will make communication easier between aircraft and ground stations, other aircraft, ships, and coast-guard stations using the International Code of Signals.

The handbook, profusely illustrated in colour, is divided into three parts. Part I describes the signals laid down by the International Air Convention of 1919, and illustrates the national flags and aircraft distinguishing marks of the world, both civil and military. This part also includes sections on navigation, mooring, and aerodrome lights and signals, all of which are particularly clearly illustrated in colour. Part II contains instructions in the methods of sending and receiving messages, and Part III is an extract from the International Code of Signals, sufficient to admit the coding and decoding of messages. The latter contains one, two, and three-letter groups each arranged alphabetically, which makes decoding easy, while for coding there is an alphabetical vocabulary. This is the usual arrangement in signalling handbooks, but in this case the signals and vocabulary are particularly applicable to air navigation and inter-communication rather than to normal maritime use.

THE INTERNAL COMBUSTION ENGINE.

By C. F. Taylor, Ph.B., M.E., and E. S. Taylor, B.S. Published by the International Textbook Co., Scranton, Pennsylvania. Price $3.50.

This book is intended by the authors to provide an understanding of the functioning of the internal combustion engine so as to facilitate design or research.

With this idea as a basis the effect of the various variables has been expressed in the form of curves, and in certain cases mathematically.

The authors are respectively the Professor of Automotive Engineering and the Assistant Professor of Aeronautical Engineering at Massachusetts Institute of Technology, and it may be said that their book is an excellent synopsis of the existing knowledge of internal combustion engines. It suffers from the defect that almost all the information given is derived from United States services and that little reference is given to the important researches which have been given in this country as well as others; in fact, it is probable that some of this work would have caused the authors to modify their opinion on certain matters; for instance, the wear or corrosion of engine cylinders, but in spite of this those who wish to understand the present position of engine research will find this book very valuable.

An important feature is the excellent bibliography which occupies about twenty-five pages of small print, almost entirely drawn from American sources, this being a feature which might well be copied by other textbooks, though the almost complete absence of reference to European sources is regrettable. From the British point of view this textbook is much nearer what a book of this type should be, than many of the books of this nature which reach us from America.